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HUGHES TOOL COMPANY · AIRCRAFT DIVISION
Culver City, California

Report 285-12(62-12)

HOT CYCLE ROTOR SYSTEM

DETAIL DESIGN OF ROTOR

MARCH 1962

For

Commander

Aeronautical Systems Division

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FOREWORD

This report has been prepared by Hughes Tool Company -- Aircraft Division under USAF Contract AF 33(600)-30271 "Hot Cycle Pressure Jet Rotor System," D/A Project Number 9-38-01-000, Subtask 616.

The Hot Cycle Pressure Jet Rotor System is based on a principle wherein the exhaust gases from high pressure ratio turbojet engine(s) located in the fuselage are ducted through the rotor hub and blades and are exhausted through a nozzle at the blade tips. Forces thus produced drive the rotor.

The objective of this contract was to prove feasibility of the Hot Cycle Pressure Jet concept by design, fabrication and test of a complete rotor.

This report covers that portion of the work pertaining to the detail design of the rotor. It is submitted in partial fulfillment of Item 4e, covering Design of the Rotor System, performed under Item 4a of the contract. Although the main body of the report was completed some time ago, its submittal was withheld in order to permit inclusion of changes which occurred as the tests progressed.

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SECTION 1

SUMMARY

This report covers the detailed structural and mechanical design of the Hot Cycle Rotor System. As shown schematically on the perspective sketch in Figure 1-1 of the page opposite, the rotor system consists of a free-floating hub and three coning blades mounted on a shaft supported by an upper radial bearing and a lower thrust bearing. These bearings are positioned above the whirl tower (or fuselage) by a steel tubular truss.

Characteristics associated with this design are:

1. A structure which lends itself to early production with existing equipment and techniques.
2. A segmented blade which provides protection for the primary members and allows replacement of individual components if damage does occur.
3. High temperature metals such as Rene' 41, Inconel X, and Haynes 25 incorporated where advantage can be taken of their particular characteristics.
4. Seals for 1200°F gases consisting of carbon vs. type 347 corrosion resistant steel, and Rene' 41 vs. Tungsten Carbide Flame Plate.
5. Titanium spars which by nature of the design, are protected from damage in handling or in rotor operation.
6. Multiple lamination blade retention straps of corrosion resistant steel.
7. Steel and alloy spot welded rotor blade segments.
8. A non-lubricated mono-ball type feathering-coning bearing utilizing a chrome plated aluminum ball and a teflon race.
9. A conventional control system.

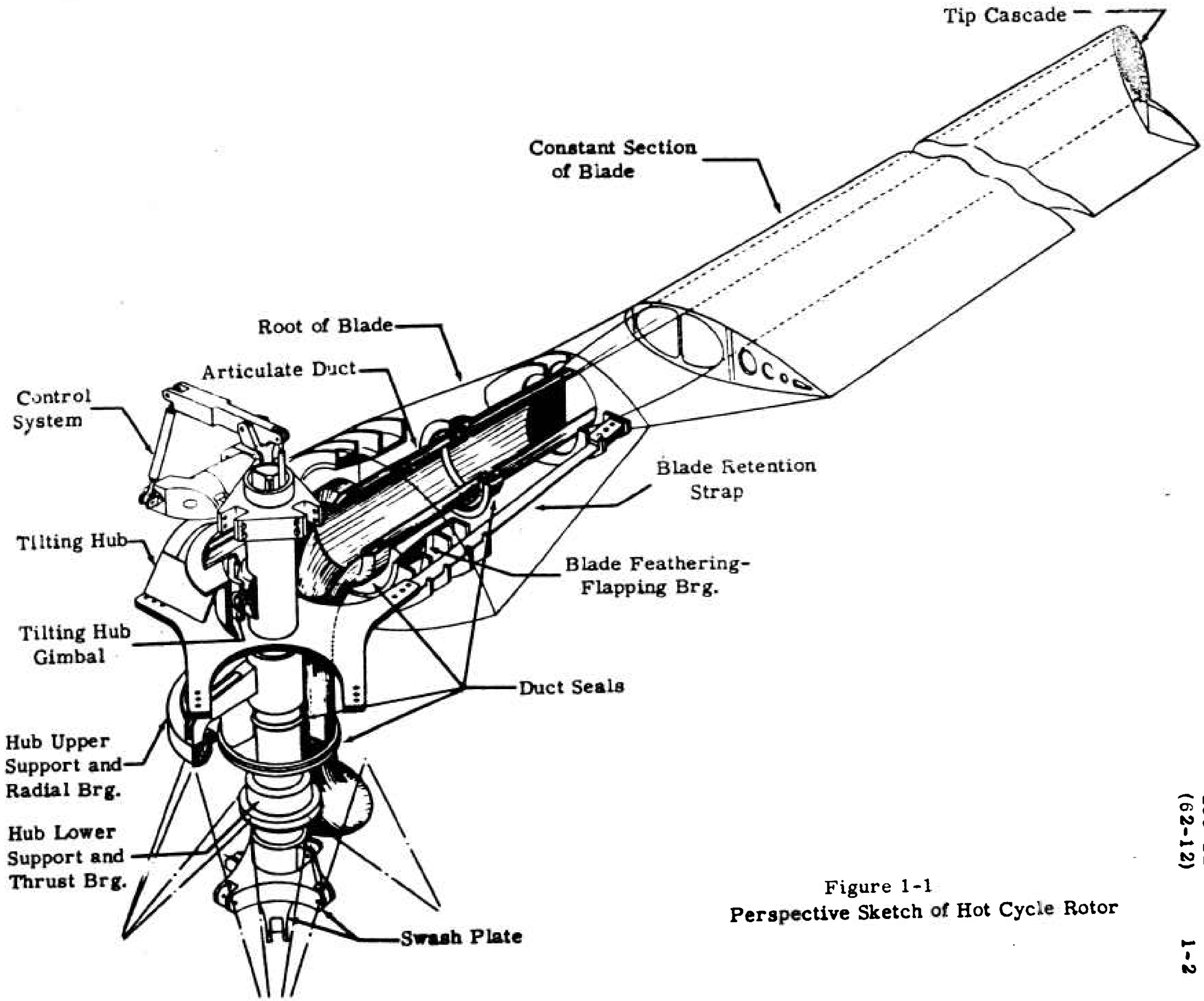


Figure 1-1
Perspective Sketch of Hot Cycle Rotor

SECTION 2

GENERAL INTRODUCTION

This detail design was initiated by an analysis of temperatures, loads, and control movements which are reported in Refs. 3-3 and 7-1 and of the Design Criteria included as Appendix 1. The Rotor System was designed for a helicopter of 15,300 pounds gross weight,[1] a load factor of 2.5 and the full output of two General Electric T64 engines.[2]

The following pages outline the philosophy and decisions applicable to the detail design of the rotor. Details of construction and/or fabrication are given where they are considered more or less unique to the Hot Cycle Rotor System.

Where helpful, schematic drawings and photographs of actual parts are included. A complete list of the rotor system drawings is included in the Appendix for reference purposes.

1 Modification 10 of the contract
2 Modification 11 of the contract

SECTION 3

DESIGN OF ROTOR BLADE

3.1 INTRODUCTION (Figure 3-1)

The blade design performed under Item 4e is a refinement of the preliminary design made under Item 3 and described in Reference 3-1. The production design incorporates two machined titanium alloy spars that comprise the only continuous members running from the blade root to the tip. The spars are separated fifteen inches chordwise by eighteen identical sheet-metal segments 12.50 inches long, made up of two ducts contained within nine ribs and an outer cover. The segments are bolted to the spars and are joined together by bellows-type flexible couplings riveted to the outer cover. The ducts and skins of adjacent segments are slip-jointed.

In this structural arrangement the spars are the only members that react normal blade bending loads and centrifugal loads. Torsional and chordwise shear loads are carried by the assembly of segments. Advantages of this arrangement are:

(a) The principal load carrying elements of the structure are insulated from the hot gas transfer system by a dead air space between the ducts and outer cover of the segments.

(b) Loads produced by thermal expansion differences between the segments and spars are minimized by the slip-jointed, flexibly-coupled assembly of the segments.

(c) Blade natural frequencies in normal bending are kept within a safe range, in relation to resonance with integer multiples of rotor RPM, by use of the spars as the only normal bending material, depth of which can be readily controlled.

(d) Ground resonance is avoided by means of high chordwise bending stiffness resulting from the spar chordwise spacing, which holds the blade natural frequency within a safe range in relation to resonance with the fundamental rotor frequency.

(e) Repair of punctured or otherwise damaged skins and ducts can be accomplished by replacing one or more of the interchangeable segment sections.

(f) Under military emergency conditions, simple temporary patches would be feasible on punctured segments without removal from the blade, since the segments are not subjected to the major bending and centrifugal loads.

The distinctive feature of this solution of the problem of hot cycle blade design, involving the separation of the structural elements according to function, relied on only a reasonable advance in existing production technology for its realization. It did not require the development of entirely new fabrication methods or the building of new production and/or processing equipment.

3.2 DETAIL DESIGN

3.2.1 Spars (Figure 3-2)

In the course of detail design, the front spar was made much simpler in cross-sectional shape than in the preliminary design. The amount of raw stock required was reduced by one half. The front spar is now made from the same size of flat rolled bar stock as the rear spar. All curved surfaces except corner fillets have been eliminated and cross sectional dimensions have been made constant throughout the length for maximum ease of production, except for plane tapers on one face for control of stiffness and weight. The thickness of both spars at the center line, where they are bolted to the segments, is untapered so that bolts of uniform length may be used.

The front and rear spars are milled from flat-rolled bar stock of 6AL-4V titanium alloy, purchased in lengths sufficient to make the spars without splicing. It is believed that these are the longest bars of this material ever produced for a specific purpose. Physical properties as determined by tensile tests exceed those guaranteed for thinner stock. After machining, the rear spar is shot peened to enhance the fatigue strength of the material and thus to allow the spar to be of lighter weight. The front spar, because of its secondary function as a blade chordwise balance weight, contains material in excess of the amount required for strength. As a result, stresses in the front spar are relatively low and shot peening is not indicated.

To further increase the strength of the spars, it was decided to air cool them during rotor operation by taking advantage of the inherent centrifugal pumping action of the rotor. The changes made in the front spar during detail design provide an appropriate space between the spar

and the leading edge skin which acts as a duct. A cooling air tunnel for the rear spar has been formed by revising the blade aft segment to add a web parallel to the spar. Discharge orifices for the cooling air have been incorporated in the tip cascade. No other changes or additions were required for this cooling system.

A shim of low friction material was installed between the spars and blade segments to prevent fretting of the contacting surfaces. Teflon [1] was known to perform this function well at the temperatures expected in this area. Trial of a sprayed teflon coating during the Flexural Fatigue and Screening Test had demonstrated that the teflon layer should have a minimum thickness in the order of .010 inch, so that some local wear and cold flow of the protective material may take place without allowing metal-to-metal contact at high spots. It is also desirable that the teflon be restrained from cold flow. Two of the most promising materials having these characteristics were tested in a simple set-up duplicating the temperature and relative motions of spar and segment during rotor operation. One material was Fabroid, [2] a fabric of teflon filaments interwoven with glass fiber thread; the other was Armalon, [1] a teflon coated glass fiber fabric. Both performed satisfactorily. Armalon was chosen for use on the blade, as it is cheaper and easier to work.

A unique property of teflon is that bits of material small enough to become lodged between the spar and segment will be imbedded in the Armalon, become coated with teflon and thus be prevented from scratching the spar or segment.

3.2.2 Blade Segments (Figures 3-3, 3-4.)

The blade segments are identical sheet metal assemblies consisting of two ducts contained within nine ribs and an outer cover. Each segment is 12.50 inches spanwise and 15.00 inches chordwise. The ribs are die-formed with flanges matching the airfoil and duct contours.

On the basis of experience gained while making specimen segments for the Flexural Fatigue and Screening Test, (Reference 3-2), it was decided to assemble the production segments entirely by spot and seam welding, rather than by brazing as had been planned during the preliminary design stage. Spot welding eliminates the potential distortion problems associated with the brazing process, and spotwelded specimens performed equally as well as brazed specimens in the flexural fatigue and screening test.

1 E. I. Dupont De Nemours and Company, Inc., Wilmington, Delaware
2 Micro-Precision, Division of Micromatic Hone Company, Los Angeles, California

The ducts and the inner edges of the ribs are subjected to the full gas heat of the power system. Rene' 41 alloy sheet was chosen as material for these parts because of its outstanding strength at high temperatures (Refer to curves in Reference 3-3) and excellent corrosion resistance. The ribs and ducts were formed and spotwelded together as a sub-assembly while in the solution heat treated condition to gain advantage of the superior joints obtained between Rene' 41 parts when welding is performed prior to age hardening. This sub-assembly was then age hardened for maximum strength and the segment was completed by spot welding outer covers of type 301 corrosion resistant steel sheet.

The segment design relies entirely on existing conventional types of tooling and processes for detail fabrication and assembly. Only a moderate extension of existing techniques was required, noteable in regard to methods for spotwelding Rene' 41 sheet. It should be noted that it was not necessary to make a single change in the segment design as a result of problems encountered during manufacture

3.2.3 Flexible Couplings (Figure 3-5)

At each joint between segments of the rotor blade there is a bellows-type flexible coupling riveted to the outer cover. This coupling performs a number of functions. It provides a pressure tight enclosure around the duct slip joints, it absorbs the thermal expansion and centrifugal load deflection differences between the segments and the spars, it transfers torsional and chordwise shear loads from segment to segment, and it incorporates a high degree of flexibility into the assembly of segments so that no appreciable blade bending loads are carried by any part of the structure other than the spars. This last feature is an important factor in controlling the stiffness of the blade to hold the resonant frequency within the required limits.

The blade couplings were originally designed to be produced by the electroforming process, using pure nickel. Similar parts made by this method had performed very successfully in the Flexural Fatigue and Screening Test (Reference 3-2). However, when production of couplings in the quantity required for the rotor blades was attempted it became evident that it would take an excessively long time, even though production was split between two electroforming vendors. Fortunately, it proved possible to develop drop-hammer tooling to form the couplings from Inconel X sheet, and parts made in this manner were quickly produced and tested. The resulting coupling is made up of two identical die stampings welded together at the center line of the blade, which is the point of minimum cyclic stress. The welded assembly is heat treated and glass peened for maximum fatigue strength.

Since one of the functions of the flexible couplings is to provide a pressure-tight enclosure around the duct slip-joints, the riveted joints connecting the couplings to blade segments must be sealed. (Figure 3-6). This was accomplished by applying Dow Corning Silastic RTV 601 around the joint area inside the ends of the blade segments at the time the couplings were installed. RTV 601 is a heat-resistant, air curing silicone rubber compound applied in form of a thick liquid or paste. A detailed discussion of this material is contained in Reference 3-4.

3.2.4 Tip Cascade (Figures 3-7, 3-8)

The tip cascade is a welded assembly of contoured sheet metal parts, consisting of two elbow ducts faired into the ducts of the blade segments, four hollow-section airfoil turning vanes in each duct, and an outer cover faired into the skins of the blade. The leading and trailing edges of the assembly each incorporate a discharge orifice for the centrifugally pumped air used to cool the spars during rotor operation. The components of the cascade are joined by heliarc and spot welding.

Conventional production forming tools would be applicable to all elements of this design, but since only three cascade assemblies were needed for the whirl test, the detail parts were designed so that they could be shaped with hand tools and simple form blocks. Haynes Alloy 25 cobolt base sheet was chosen as material for the tip cascades because of its strength and dimensional stability at high temperatures, its high corrosion resistance and good welding properties.

3.2.5 Blade Root Structure (Figure 3-9)

In general, the root of the Hot Cycle rotor blade is a substantially conventional structure of ribs, frames, webs and skins, bolted to the spars. The distinctive feature of the design is that the spars are the only members reacting normal bending loads, as in the outer blade, and therefore the blade natural frequency is readily controlled by selection of spar stiffness. This effect was accomplished by dividing the sheet - metal structure into seven sections joined together by six frames with hat-type cross sections that open and close as the blade deflects, without reacting the bending loads. Torsional and chordwise shear loads are carried by the flexible frames from section to section.

The flexible frames of the blade root structure are made from pure nickel by the electroforming process. This method made possible the design of frames running around the entire periphery of the structure

without joints or splices, a decided advantage in members carrying cyclic torsion combined with flexing loads. On the two smallest of the six frames, where splicing was unavoidable because of assembly considerations, joints were made at the points of least cyclic deflection.

3.2.6 Feathering-Flapping Bearing (Figure 3-10)

For articulation with the hub, a simple monoball type of bearing is used. A ball in the form of an annular segment of a hollow sphere is mounted on the inboard end of the blade root structure and rotates within a teflon faced ring attached to the hub. The opening through the ball provides clear passage from hub into blade for the ducts of the hot gas transfer system and for cooling air flowing into the blade root.

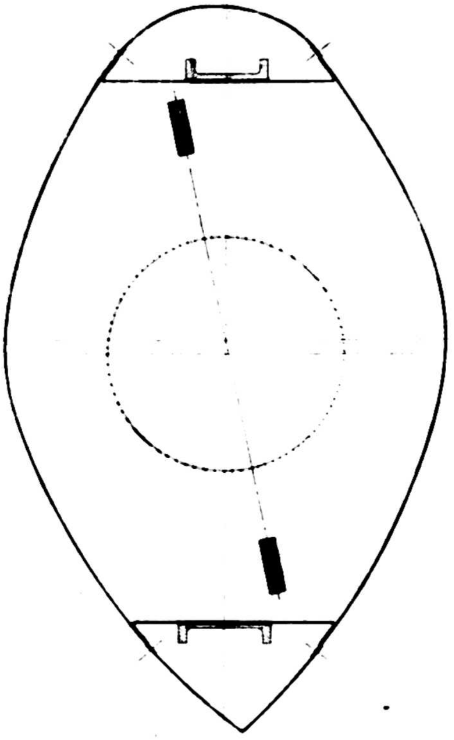
Casting was selected as the optimum method for producing the feathering ball, using type 356-T6 aluminum alloy. For light weight, the part is thin-walled with an interior system of integrally cast stiffening webs. The spherical bearing surface is chrome plated for wear resistance and low friction.

3.2.7 Trailing Edge Segments (Figure 3-11)

The aft segments of the blade are conventional interchangeable sheet-metal assemblies consisting of four ribs, a skin and a spar-type channel section tying all members at the forward end of the assembly. The channel section also functions as one wall of a tunnel for air flow to cool the blade rear spar during rotor operation. The ribs are identical flanged die-stampings. The segment is assembled by means of bonding. Skins of adjacent segments are slip jointed. The system of skin-laps between aft segments and main blade structure is designed so that any one segment may be removed or replaced by loosening the fastenings of not more than two adjacent segments.

3.2.8 Leading Edge Fairings (Figure 3-12)

The leading edge fairings are identical roll-contoured sheets of type 301 corrosion resistant steel, each as long as a blade segment. Adjacent fairings are slip-jointed. Additional roll-contoured sheets are attached to the fairings for adjustment of blade chordwise balance. Any one fairing may be removed and replaced separately.

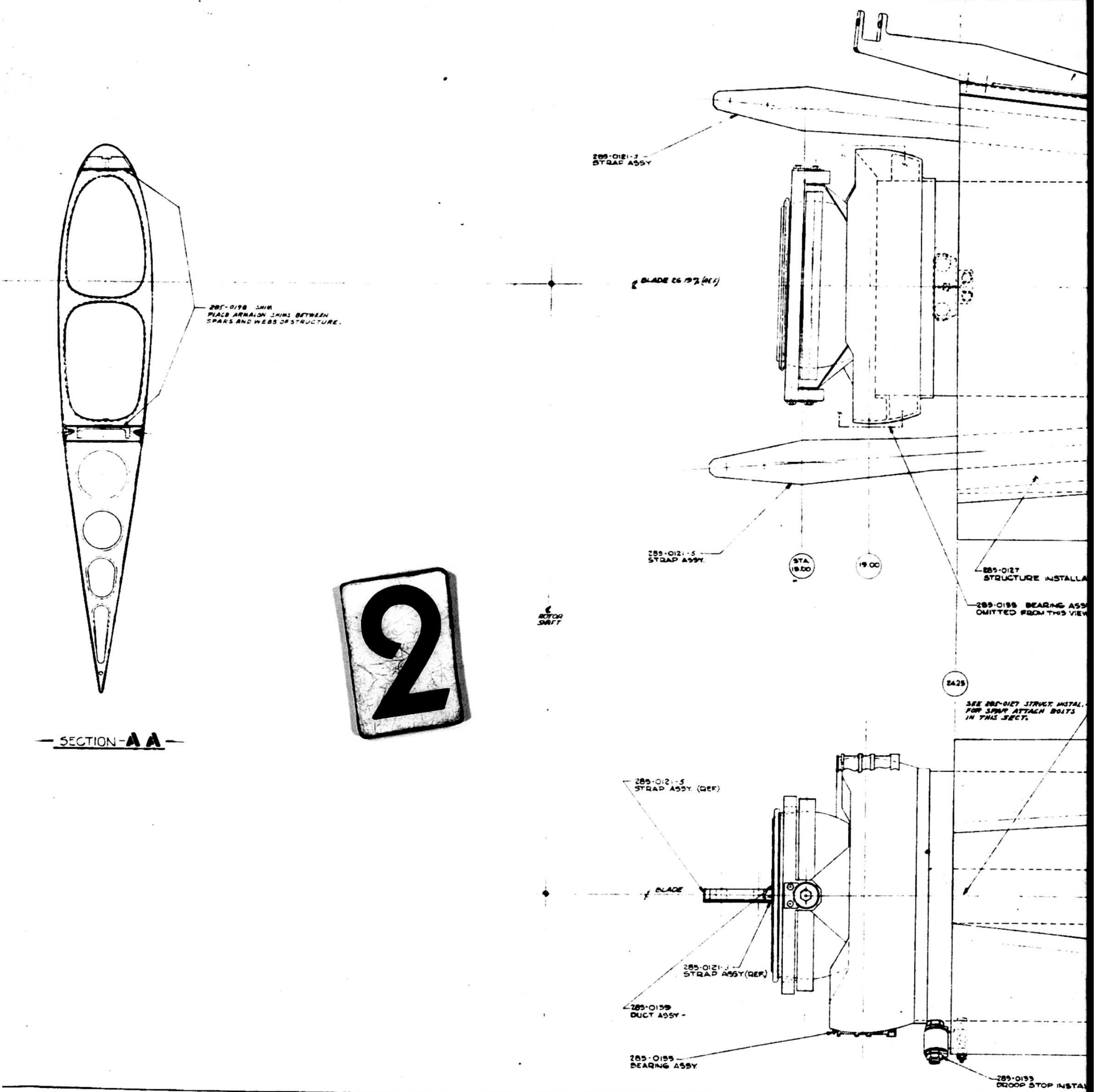


SECTION B B

1

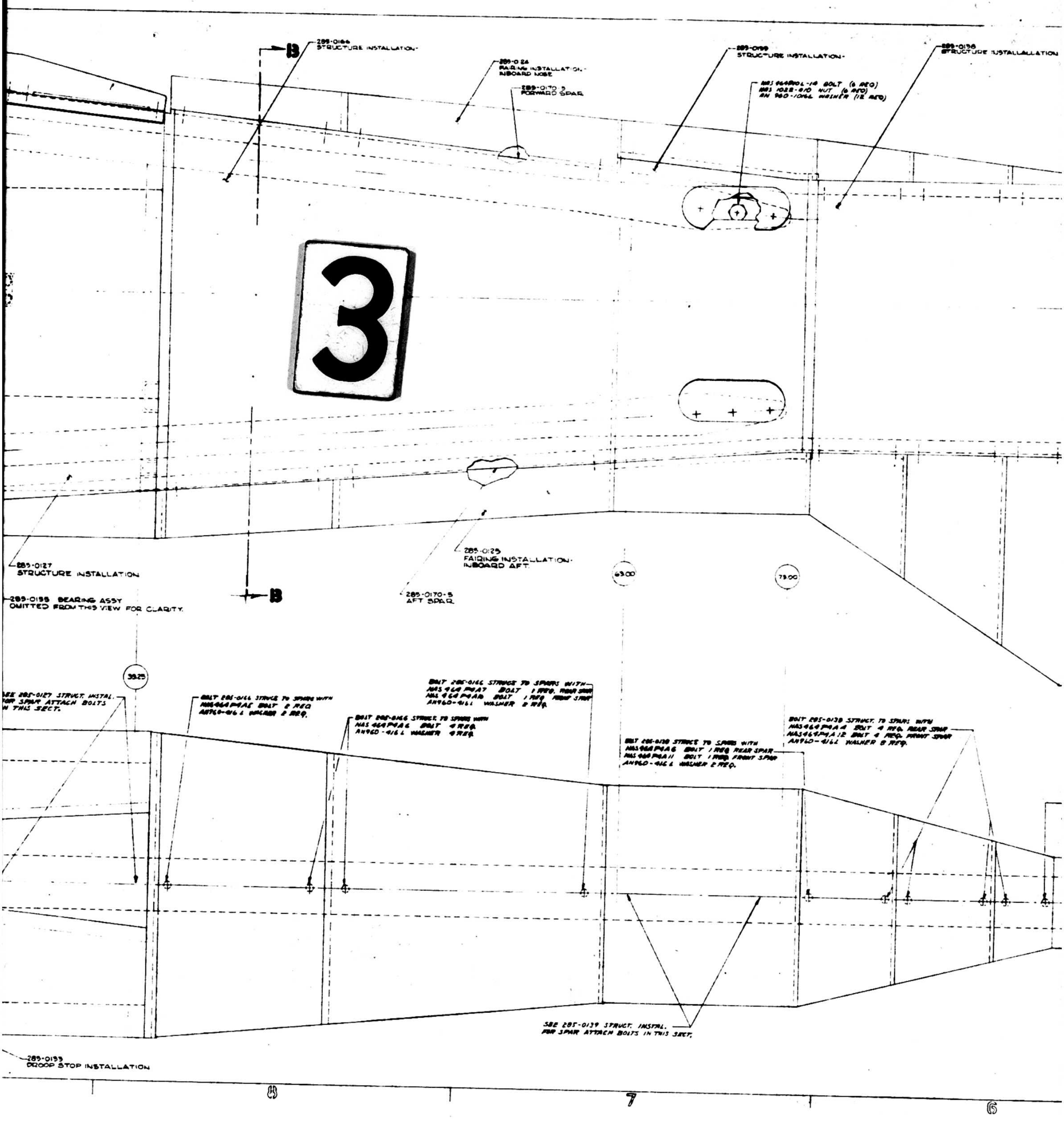
13

12

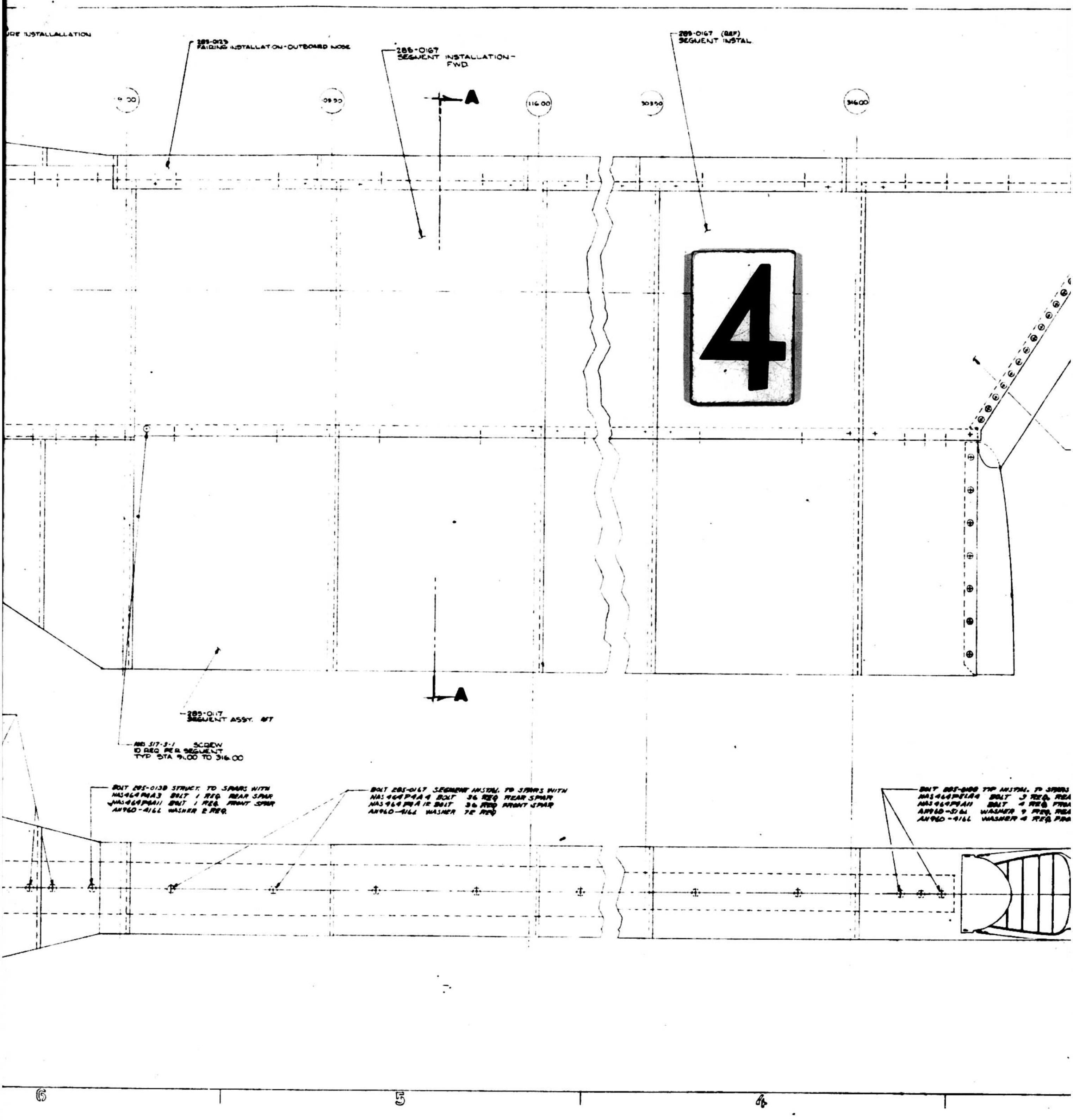


SECTION-AA

11 10 9



285-0166
STRUCTURE INSTALLATION
B
285-0124
FAIRING INSTALLATION
INBOARD NOSE
285-0170-5
FORWARD SPAR
285-0139
STRUCTURE INSTALLATION
NAS 464P10L-14 BOLT (6 REQ)
NAS 1022-010 NUT (6 REQ)
AN 960-1016L WASHER (12 REQ)
285-0138
STRUCTURE INSTALLATION
3
285-0127
STRUCTURE INSTALLATION
285-0125
FAIRING INSTALLATION
INBOARD AFT
63.00
73.00
285-0155 BEARING ASSY
OMITTED FROM THIS VIEW FOR CLARITY
B
285-0170-5
AFT SPAR
39.25
SEE 285-0127 STRUCT. INSTAL.
FOR SPAR ATTACH BOLTS
IN THIS SECT.
BOLT 285-0166 STRUCT TO SPARS WITH
NAS464P4A5 BOLT 2 REQ
AN960-416L WASHER 2 REQ.
BOLT 285-0166 STRUCT. TO SPARS WITH
NAS 464P4A6 BOLT 4 REQ
AN960-416L WASHER 4 REQ
BOLT 285-0166 STRUCT TO SPARS WITH
NAS 464 P4A7 BOLT 1 REQ. REAR SPAR
NAS 464 P4A8 BOLT 1 REQ FRONT SPAR
AN960-416L WASHER 2 REQ.
BOLT 285-0138 STRUCT TO SPARS WITH
NAS464P4A6 BOLT 1 REQ REAR SPAR
NAS464P4A11 BOLT 1 REQ FRONT SPAR
AN960-416L WASHER 2 REQ.
BOLT 285-0138 STRUCT. TO SPARS WITH
NAS464P4A4 BOLT 4 REQ. REAR SPAR
NAS464P4A12 BOLT 4 REQ. FRONT SPAR
AN960-416L WASHER 8 REQ.
SEE 285-0139 STRUCT. INSTAL.
FOR SPAR ATTACH BOLTS IN THIS SECT.
285-0133
DROOP STOP INSTALLATION
8
7
6



285-0123
FAIRING INSTALLATION-OUTBOARD NOSE
285-0167
SEGMENT INSTALLATION-FWD
285-0167 (REF)
SEGMENT INSTAL.
116.00
316.00
A
4
A
285-0117
SEGMENT ASSY. AFT
SCREW
10 REQ PER SEGMENT
TYP STA 9.00 TO 316.00
BOLT 285-0138 STRUCT. TO SPARS WITH
NAS464P4A3 BOLT 1 REQ. REAR SPAR
NAS464P4A11 BOLT 1 REQ. FRONT SPAR
AN960-416L WASHER 2 REQ.
BOLT 285-0167 SEGMENT INSTAL. TO SPARS WITH
NAS464P4A4 BOLT 36 REQ REAR SPAR
NAS464P4A12 BOLT 36 REQ FRONT SPAR
AN960-416L WASHER 72 REQ
AN960-416L WASHER 4 REQ
6
5
4

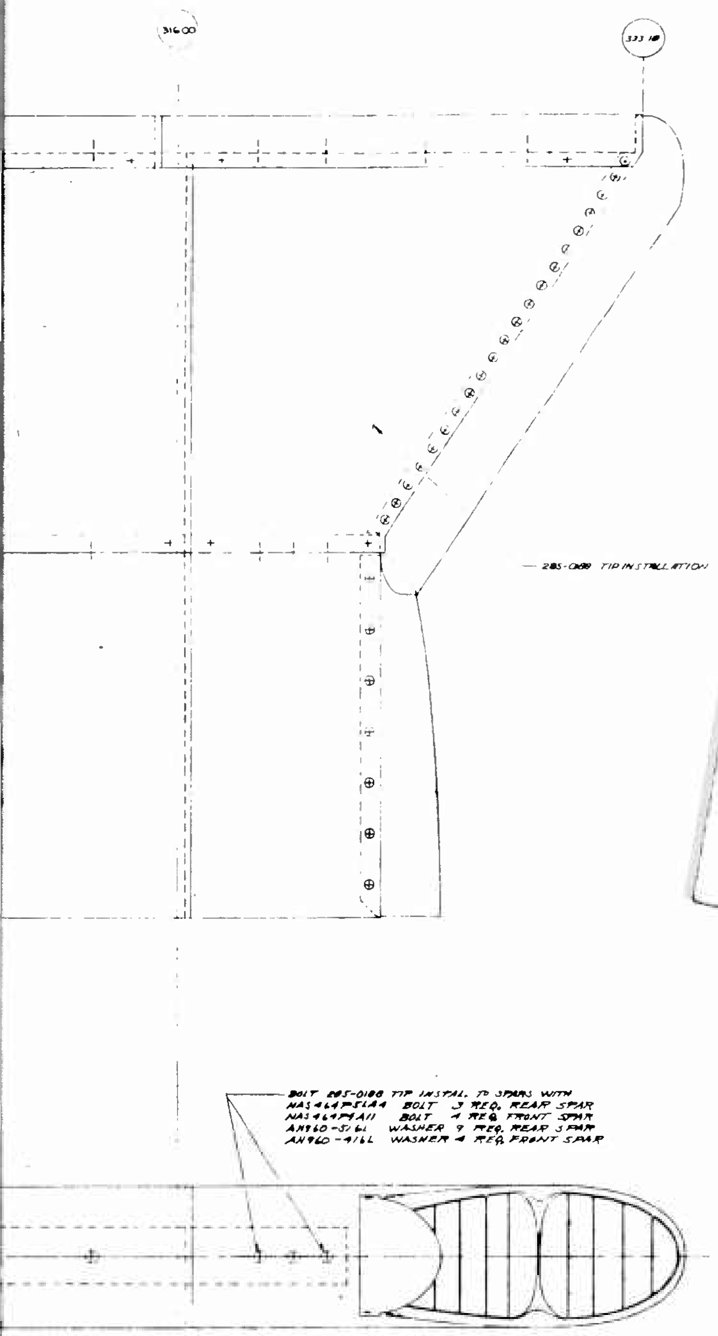


Figure 3-1.

NAS517-3-1	100	SCREW
AN960-10L	12	WASHER
NAS1022-A10	6	NUT
NAS464PCL-14	6	BOLT
NAS464PA5	2	BOLT
NAS464PA6	5	BOLT
NAS464PA7	1	BOLT
NAS464PA10	1	BOLT
NAS464PA11	6	BOLT
NAS464PA4	40	BOLT
NAS464PA12	40	BOLT
NAS464PA3	1	BOLT
NAS464P5LA4	3	BOLT
AN960-416L	96	WASHER
AN960-516L	9	WASHER
285-0198	1	SHIM
285-0133	1	DROOP

285-0188	1	TIP INST
285-0170-5	1	SPAR
285-0170-3	1	SPAR
285-0167	1	SEGM
285-0166	1	STRUC
285-0159	1	DUCT I
285-0155	1	BEAR
285-0139	1	STRUCT
285-0138	1	STRUCT
285-0127	1	STRUCT
285-0125	1	FAIRING
285-0124	1	FAIRING
285-0123	1	FAIRIN
285-0121-5	1	STRAP
285-0121-3	1	STRAP
285-0117	18	SEGMEN

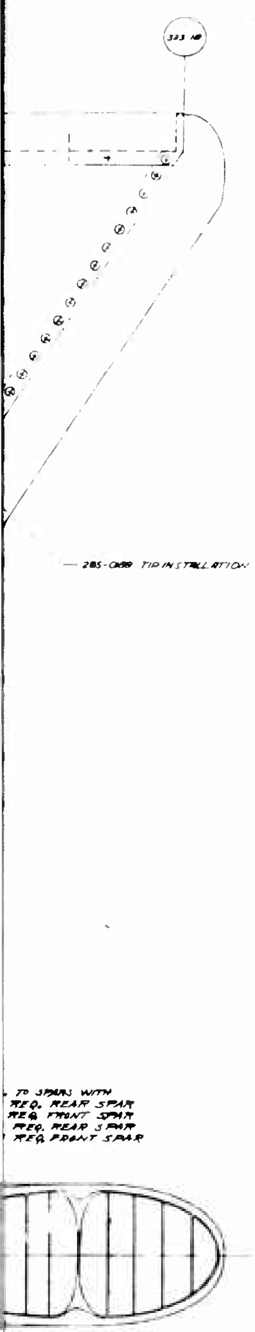


Figure 3-1

NAS517-3-1	180	SCREW	6
AN960-10L	12	WASHER	7
NAS1022-10	6	NUT	7
NAS464P10-14	6	BOLT	7
NAS464PA5	2	BOLT	8
NAS464PA6	5	BOLT	7&8
NAS464PA7	1	BOLT	7&8
NAS464PA10	1	BOLT	7&8
NAS464PA11	6	BOLT	4,6,7
NAS464PA4	40	BOLT	4,5,6
NAS464PA12	40	BOLT	5&6
NAS464PA3	1	BOLT	6
NAS464PSL4	3	BOLT	4
AN960-416L	96	WASHER	3 TO 8
AN960-516L	9	WASHER	3&4
285-0198	1	SHIM	
285-0133	1	DROOP STOP INSTALLATION	11
			9

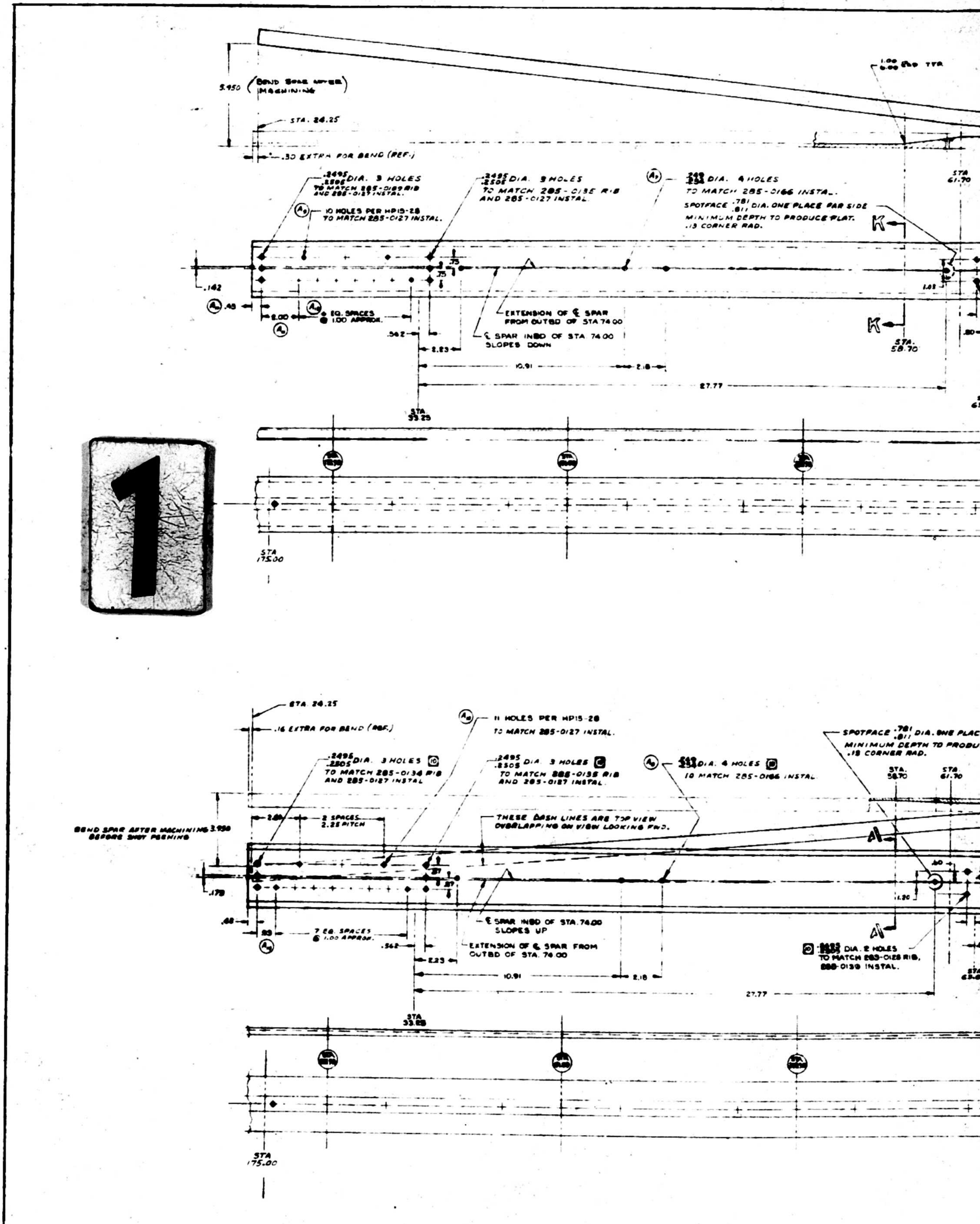
285-0100

285-0188	1	TIP INSTALLATION	3
285-0170-5	1	SPAR AFT	8
285-0170-3	1	SPAR FWD	7&8
285-0167		SEGMENT INSTALLATION	5
285-0166		STRUCTURE INSTALLATION	9
285-0159	1	DUCT INSTALLATION	10
285-0155	1	BEARING ASSY	10
285-0139		STRUCTURE INSTALLATION	7
285-0138	1	STRUCTURE INSTALLATION	6
285-0127		STRUCTURE INSTALLATION	8&9
285-0125	1	FAIRING INSTALLATION - INBD AFT	7&8
285-0124		FAIRING INSTALLATION - INBD NOSE	7
285-0123		FAIRING INSTALLATION - OUTBD NOSE	5&6
285-0121-5	1	STRAP ASSY - REAR	10
285-0121-3	1	STRAP ASSY - FRONT	10
285-0117	18	SEGMENT ASSY - AFT	5&6

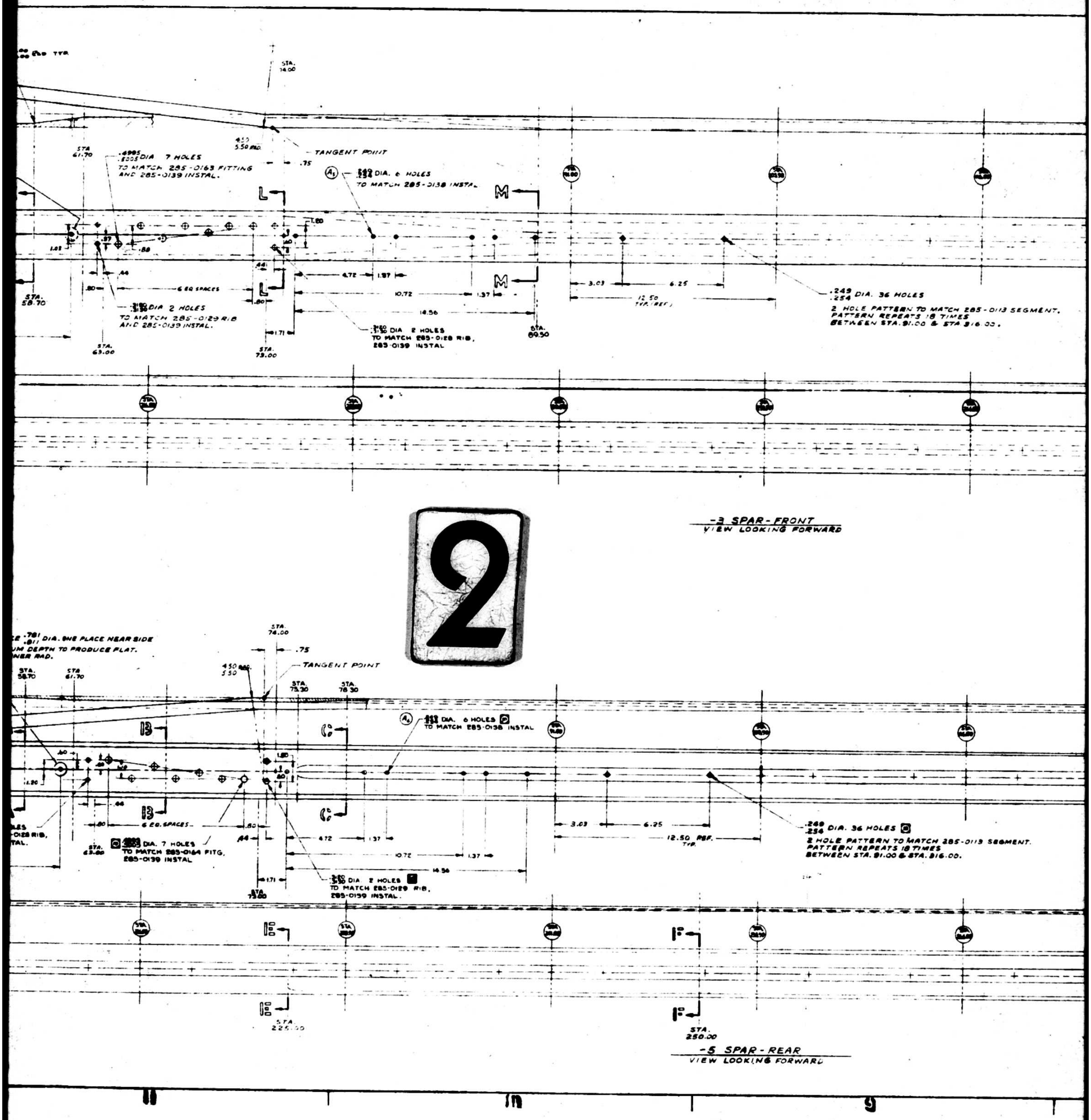
BLADE ASSY - (FIGURE 3-1)
HOT CYCLE MAIN ROTOR

AIRCRAFT DIVISION
CULVER CITY, CALIFORNIA

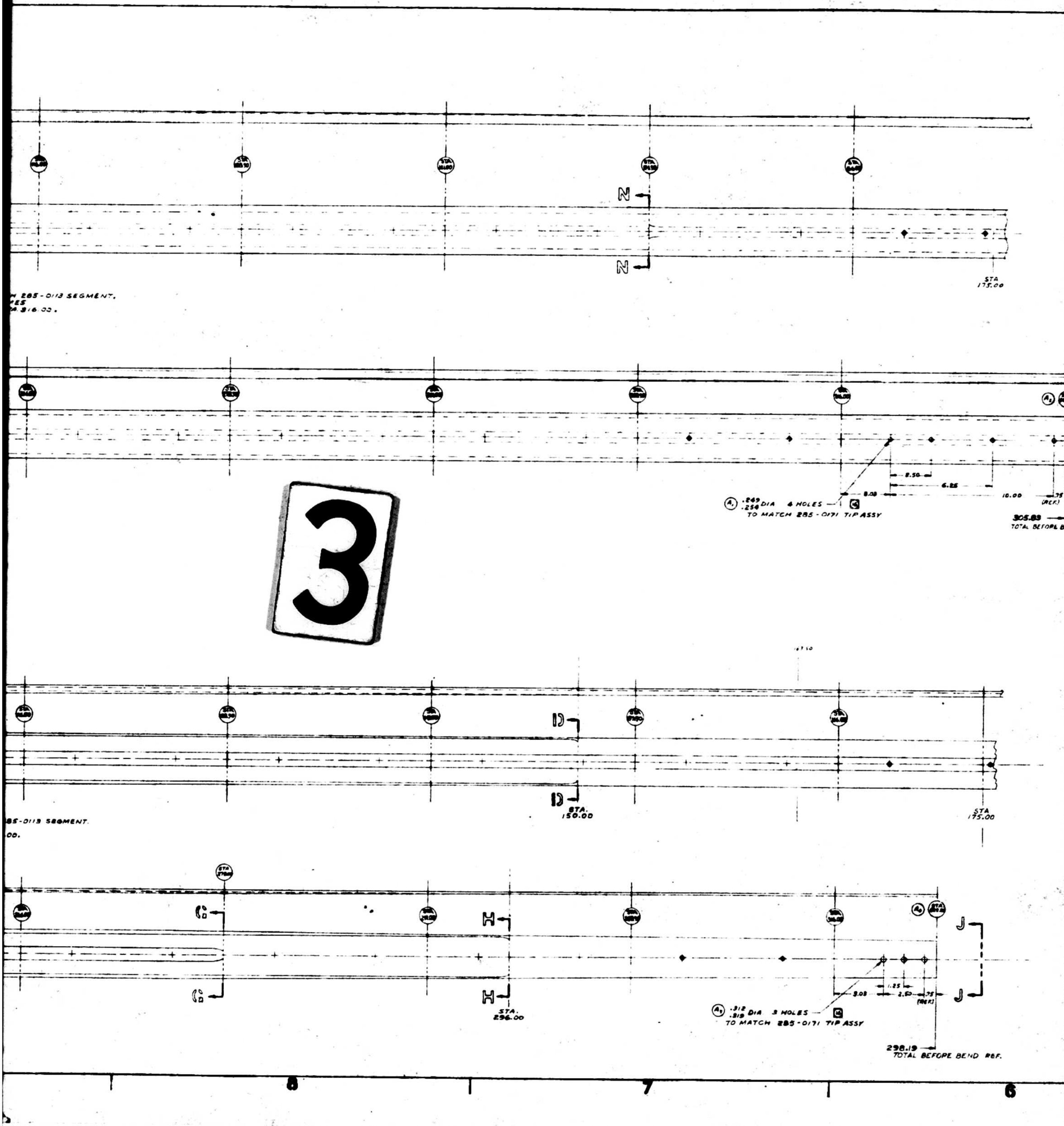
285-0100



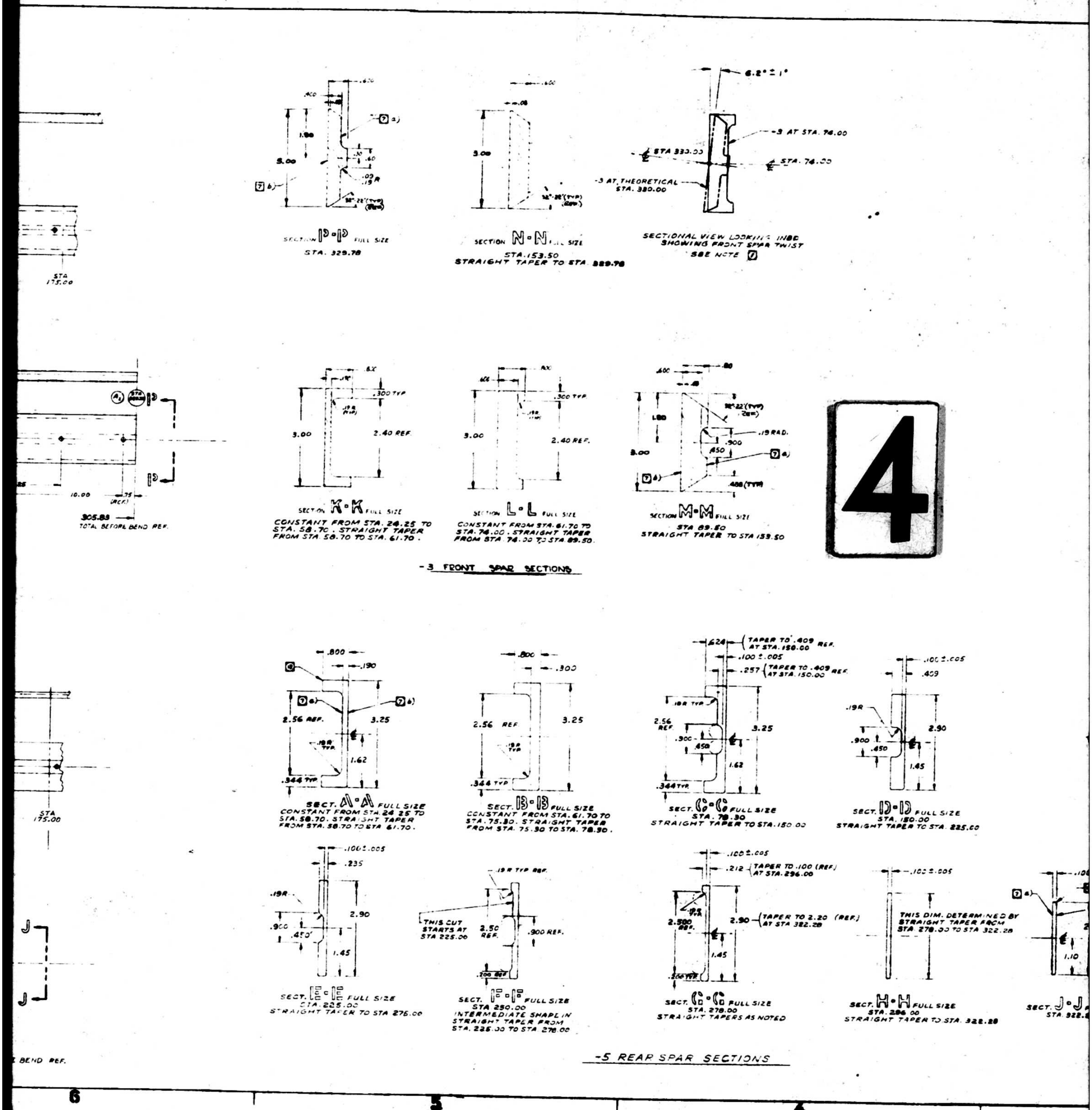
3.950 (BEND SPAR AFTER MACHINING)
STA. 24.25
.30 EXTRA FOR BEND (REF.)
DIA. 3 HOLES TO MATCH 285-0127 INSTAL.
10 HOLES PER HP15-28 TO MATCH 285-0127 INSTAL.
DIA. 3 HOLES TO MATCH 285-0135 RIB AND 285-0127 INSTAL.
DIA. 4 HOLES TO MATCH 285-0166 INSTAL.
MINIMUM DEPTH TO PRODUCE FLAT.
.13 CORNER RAD.
EXTENSION OF ℄ SPAR FROM OUTBD OF STA 74.00
℄ SPAR INBD OF STA 74.00 SLOPES DOWN
STA. 58.70
STA 61.70
27.77
STA 33.25
1
STA 175.00
STA. 24.25
.16 EXTRA FOR BEND (REF.)
11 HOLES PER HP15-28 TO MATCH 285-0127 INSTAL.
THESE DASH LINES ARE TOP VIEW OVERLAPPING ON VIEW LOOKING FWD.
BEND SPAR AFTER MACHINING BEFORE SHOT PEENING 3.950
2 SPACES 2.25 PITCH
7 EQ. SPACES
℄ SPAR INBD OF STA. 74.00 SLOPES UP
EXTENSION OF ℄ SPAR FROM OUTBD OF STA. 74.00
10.91
2.18
STA. 175.00



TANGENT POINT
.4995 / .5005 DIA. 7 HOLES TO MATCH 285-0163 FITTING AND 285-0139 INSTAL.
DIA. 6 HOLES TO MATCH 285-0138 INSTAL.
DIA. 2 HOLES TO MATCH 285-0129 RIB AND 285-0139 INSTAL.
DIA. 2 HOLES TO MATCH 285-0128 RIB, 285-0139 INSTAL
.249 / .254 DIA. 36 HOLES
2 HOLE PATTERN TO MATCH 285-0113 SEGMENT. PATTERN REPEATS 18 TIMES BETWEEN STA. 91.00 & STA. 316.00.
6 EQ SPACES
-3 SPAR - FRONT
VIEW LOOKING FORWARD
2
.781 / .811 DIA. ONE PLACE NEAR SIDE
DIA. 7 HOLES TO MATCH 285-0164 FITG. 285-0139 INSTAL
DIA. 6 HOLES TO MATCH 285-0138 INSTAL
DIA. 2 HOLES TO MATCH 285-0129 RIB, 285-0139 INSTAL.
.249 / .254 DIA. 36 HOLES
2 HOLE PATTERN TO MATCH 285-0113 SEGMENT. PATTERN REPEATS 18 TIMES BETWEEN STA. 91.00 & STA. 316.00.
STA. 225.00
STA. 250.00
-5 SPAR - REAR
VIEW LOOKING FORWARD

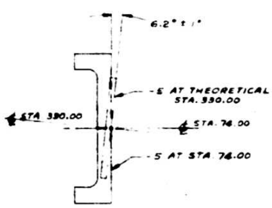


N
N
STA 175.00
285-0113 SEGMENT,
8.50
6.25
8.08
10.00
.75 (REF)
A1 .249 .254 DIA 4 HOLES
TO MATCH 285-0171 TIP ASSY
305.83
TOTAL BEFORE BE
3
D
D
STA. 150.00
STA 175.00
285-0113 SEGMENT.
G
G
H
H
STA. 296.00
J
J
1.25
8.08
2.50
.75 (REF)
A2 .312 .319 DIA 3 HOLES
TO MATCH 285-0171 TIP ASSY
298.19
TOTAL BEFORE BEND REF.
8
7
6

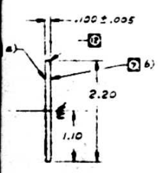

SECTION P-P FULL SIZE
STA. 329.78
SECTION N-N FULL SIZE
STA. 153.50
STRAIGHT TAPER TO STA. 329.78
6.2° ± 1°
-3 AT STA. 74.00
STA 330.00
STA. 74.00
-3 AT THEORETICAL STA. 330.00
SECTIONAL VIEW LOOKING INBD SHOWING FRONT SPAR TWIST
SEE NOTE 7
STA 175.00
305.83
TOTAL BEFORE BEND REF.
10.00
.75 (REF)
SECTION K-K FULL SIZE
CONSTANT FROM STA. 24.25 TO STA. 58.70. STRAIGHT TAPER FROM STA. 58.70 TO STA. 61.70.
3.00
2.40 REF.
.300 TYP
SECTION L-L FULL SIZE
CONSTANT FROM STA. 61.70 TO STA. 74.00. STRAIGHT TAPER FROM STA. 74.00 TO STA. 89.50.
SECTION M-M FULL SIZE
STA 89.50
STRAIGHT TAPER TO STA 153.50
.19 RAD.
.900
.450
.488 (TYP)
4
-3 FRONT SPAR SECTIONS
SECT. A-A FULL SIZE
CONSTANT FROM STA 24.25 TO STA. 58.70. STRAIGHT TAPER FROM STA. 58.70 TO STA 61.70.
.800
.190
2.56 REF.
3.25
1.62
.344 TYP
SECT. B-B FULL SIZE
CONSTANT FROM STA. 61.70 TO STA. 75.30. STRAIGHT TAPER FROM STA. 75.30 TO STA. 78.30.
.300
SECT. C-C FULL SIZE
STA. 78.30
STRAIGHT TAPER TO STA. 150.00
.624
TAPER TO .409 REF. AT STA. 150.00
.100 ± .005
.257
TAPER TO .409 REF. AT STA. 150.00
.19R TYP
SECT. D-D FULL SIZE
STA. 150.00
STRAIGHT TAPER TO STA. 225.00
.409
2.90
1.45
SECT. E-E FULL SIZE
STA. 225.00
STRAIGHT TAPER TO STA 276.00
.235
SECT. F-F FULL SIZE
STA 250.00
INTERMEDIATE SHAPE IN STRAIGHT TAPER FROM STA. 225.00 TO STA 276.00
.19 R TYP REF.
THIS CUT STARTS AT STA 225.00
2.50 REF.
.900 REF.
.200 REF
SECT. G-G FULL SIZE
STA. 276.00
STRAIGHT TAPERS AS NOTED
.212
TAPER TO .100 (REF) AT STA. 296.00
TAPER TO 2.20 (REF.) AT STA 322.28
2.500 REF.
SECT. H-H FULL SIZE
STA. 296.00
STRAIGHT TAPER TO STA. 322.28
THIS DIM. DETERMINED BY STRAIGHT TAPER FROM STA 276.00 TO STA 322.28
SECT. J-J
1.10
BEND REF.
-5 REAR SPAR SECTIONS
6
5
4

A	1	SEE CHANGE NOTICE	

5



SECTIONAL VIEW LOOKING INBD SHOWING REAR SPAR TWIST
SEE NOTE 1



SECT. J - J FULL SIZE
STA. 322.28

NOTES:

1. BETWEEN STA. 74.00 & STA. 330 TWIST SPARS 6.2° ± 1° CLOCKWISE LOOKING INBOARD. TWIST IS TO BE AT A CONSTANT RATE PER FOOT.
2. FLATNESS OF FINISHED SPAR TO BE WITHIN .010 IN 10 INCHES IN ANY REGION, NOT INCLUDING TWIST.
3. TOLERANCE ON BAR ONLY - THICKNESS ± .030; STRAIGHTNESS, .060 IN ANY 36 INCHES ANY DIRECTION
4. MINIMUM MATERIAL PROPERTIES TO BE:

ULTIMATE TENSILE STRENGTH	130,000 PSI
YIELD TENSILE STRENGTH @ 0.2% OFFSET	140,000 PSI
ELONGATION IN 2 INCHES	10% LONG, 8% TRANSV.
REDUCTION IN AREA	25% LONG, 20% TRANSV.

   A 4.80 INCH LENGTH SPECIMEN MUST BE TAKEN FROM EACH BAR & SUBMITTED TO ENGINEERING FOR TEST & APPROVAL BEFORE ACCEPTANCE OF THE RAW MATERIAL. IDENTIFY TEST BAR WITH SPAR
5. RAW STOCK TO BE ULTRASONIC INSPECTED PER HP6-22 CLASS 1A BEFORE ACCEPTANCE BY H.T.C.A.D..
6. AFTER MACHINING, BENDING & STRAIGHTENING, QUALITY CONTROL STANDARDS TO BE PER HP6-20
7. TOLERANCES & ALLOWANCES SHALL BE PER HS-217 EXCEPT AS FOLLOWS:
   a) .020 MAX MISMATCH WITH .125 MIN. FILLET RADIUS ACCEPTABLE ON ALL SURFS EXCEPT FLAT FACE OF SPAR.
   b) NO MISMATCH PERMITTED IN AREA OF BOLT HOLES OR ON FLAT FACE OF SPAR.
8. 125√ MACHINE FINISH ALL OVER.
9. SPARS TO BE BENT WITH PART AT 900°F MIN., 1000°F MAX. FOR 1 HR. MAX.
10. IT WILL BE OPTIONAL TO DRILL HOLES IN -5 EITHER BEFORE OR AFTER SHOT PEENING. ENDS OF HOLES DRILLED BEFORE PEENING MUST BE ROUNDED OFF WITH .005 TO .010 RADIUS. DO NOT SUBSTITUTE CHAMFER FOR RADIUS.
11. AFTER BENDING & STRESS RELIEF, SHOT PEEN -5 PER HP4-36 EXCEPT THAT INTENSITY SHALL BE .004 A2 TO .006 A2.
12. ALL EXTERNAL CORNERS OF -5 TO BE ROUNDED OFF WITH .020 RADIUS BEFORE SHOT PEENING. DO NOT SUBSTITUTE CHAMFER FOR RADIUS.
13. STRESS RELIEVE -3 & -5 AT 1000 ± 30°F FOR 4 +1/-0 HRS, WITH FURNACE ATMOSPHERE SLIGHTLY OXIDIZING -5 TO BE STRESS RELIEVED BEFORE SHOT PEENING.
14. DO NOT IMPRESSION STAMP.
15. TAG IDENTIFY.
16.

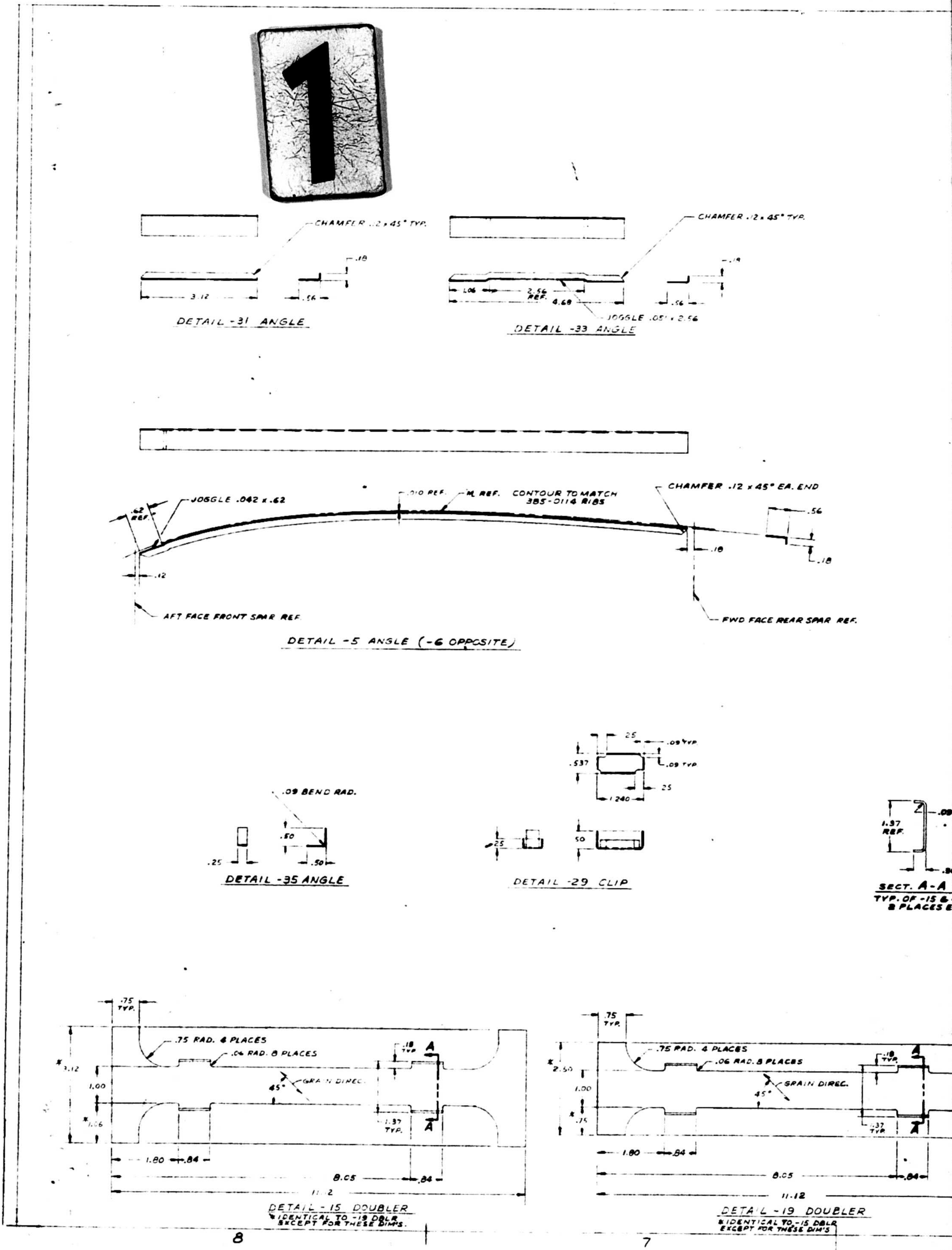
285-0170
A

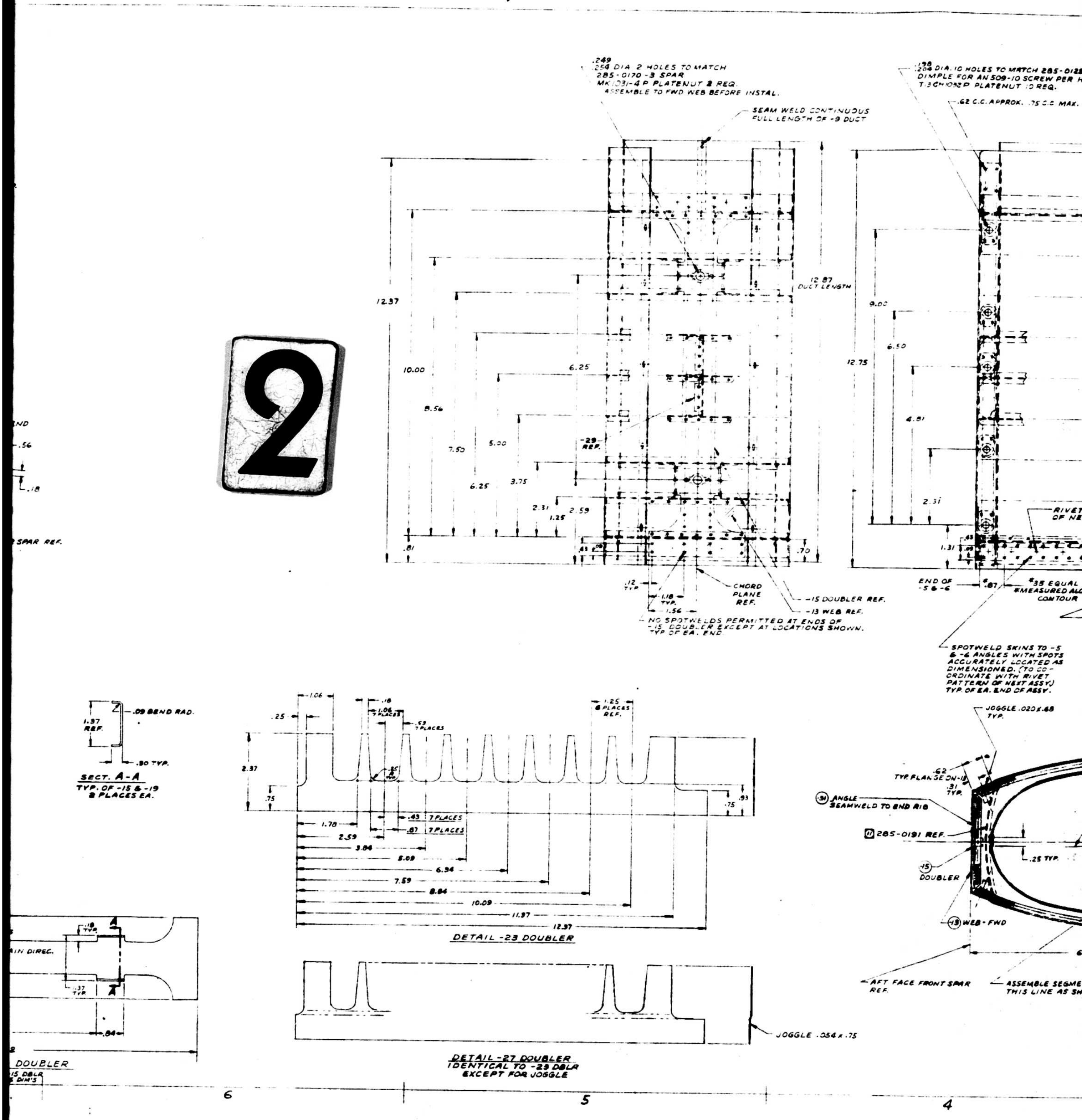
Figure 3-2.

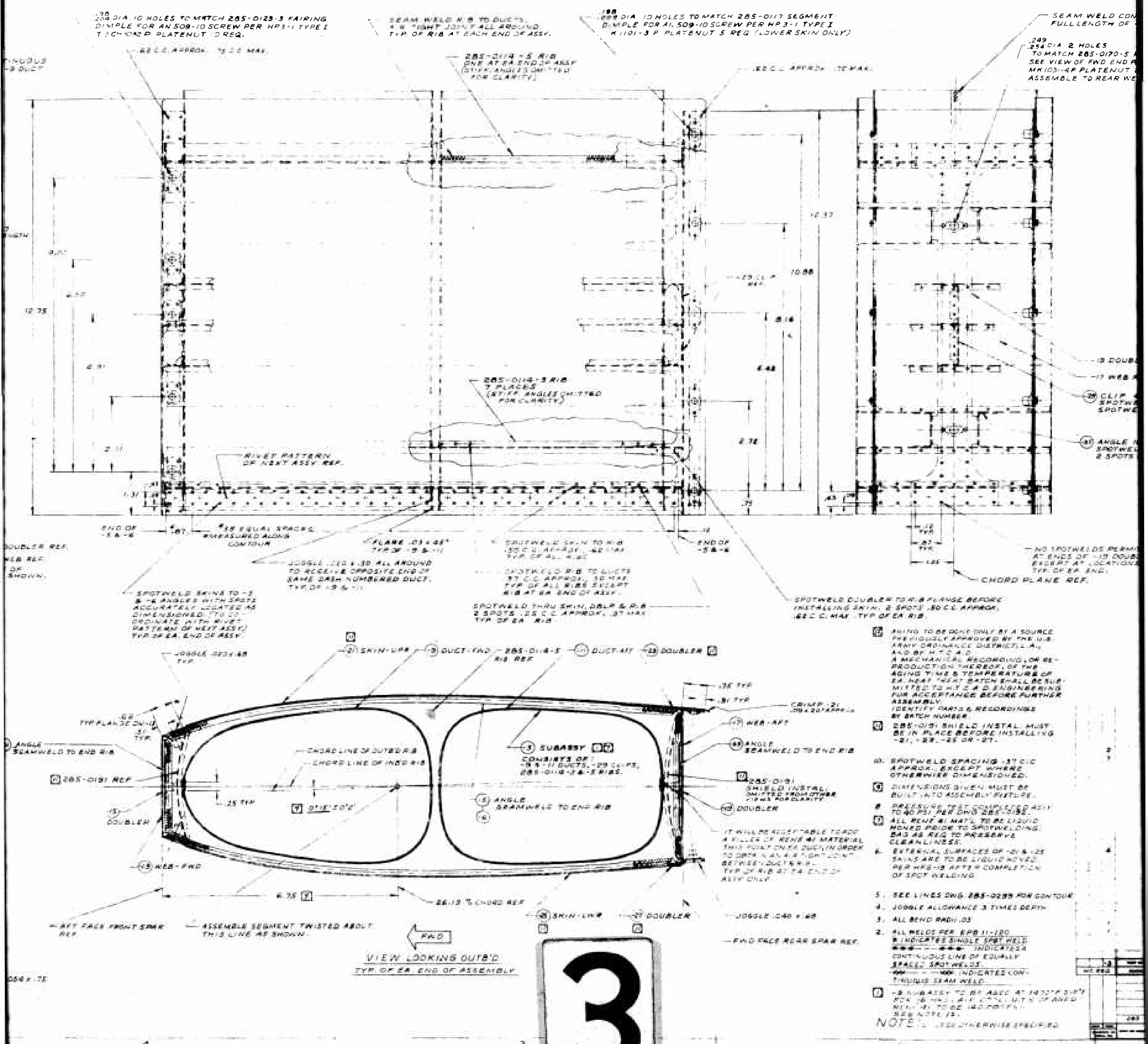
SPARS - HOT CYCLE ROTOR BLADE

285-0170

CODE 82731


1
CHAMFER .12 x 45° TYP.
.18
3.12
.56
DETAIL -31 ANGLE
CHAMFER .12 x 45° TYP.
.18
1.06
2.56 REF.
4.68
.56
JOGGLE .051 x 2.56
DETAIL -33 ANGLE
JOGGLE .042 x .62
.62 REF.
.010 REF.
℄ REF.
CONTOUR TO MATCH 385-0114 RIBS
CHAMFER .12 x 45° EA. END
.56
.18
.18
.12
AFT FACE FRONT SPAR REF.
FWD FACE REAR SPAR REF.
DETAIL -5 ANGLE (-6 OPPOSITE)
.09 BEND RAD.
.50
.25
.50
DETAIL -35 ANGLE
.25
.09 TYP
.537
.09 TYP
.25
1.240
.25
.50
DETAIL -29 CLIP
1.37 REF.
SECT. A-A
TYP. OF -15 &
2 PLACES E
.75 TYP.
.75 RAD. 4 PLACES
.06 RAD. 8 PLACES
.18 TYP
A
*3.12
1.00
45°
GRAIN DIREC.
*1.06
1.37 TYP.
A
1.80
.84
8.05
.84
11.12
DETAIL -15 DOUBLER
*IDENTICAL TO -19 DBLR EXCEPT FOR THESE DIM'S.
.75 TYP.
.75 RAD. 4 PLACES
.06 RAD. 8 PLACES
.18 TYP.
*2.50
1.00
45°
GRAIN DIREC.
*.75
.437 TYP.
1.80
.84
8.05
.84
11.12
DETAIL -19 DOUBLER
*IDENTICAL TO -15 DBLR EXCEPT FOR THESE DIM'S
8
7


.249
.254 DIA. 2 HOLES TO MATCH
285-0170-3 SPAR
MK1031-4 P PLATENUT 2 REQ.
ASSEMBLE TO FWD WEB BEFORE INSTAL.
SEAM WELD CONTINUOUS
FULL LENGTH OF -9 DUCT
12.87
DUCT LENGTH
.62 C.C. APPROX. .75 C.C. MAX.
-29
REF.
CHORD
PLANE
REF.
-15 DOUBLER REF.
-13 WEB REF.
NO SPOTWELDS PERMITTED AT ENDS OF
-15 DOUBLER EXCEPT AT LOCATIONS SHOWN.
TYP OF EA. END
END OF
-5 & -6
SPOTWELD SKINS TO -5
& -6 ANGLES WITH SPOTS
ACCURATELY LOCATED AS
DIMENSIONED. (TO CO-
ORDINATE WITH RIVET
PATTERN OF NEXT ASSY.)
TYP. OF EA. END OF ASSY.
JOGGLE .020 x .68
TYP.
TYP. FLANGE ON -15
ANGLE
SEAMWELD TO END RIB
285-0191 REF.
DOUBLER
WEB - FWD
.25 TYP.
AFT FACE FRONT SPAR
REF.
.09 BEND RAD.
1.37
REF.
.30 TYP.
SECT. A-A
TYP. OF -15 & -19
2 PLACES EA.
7 PLACES
6 PLACES
REF.
DETAIL -23 DOUBLER
JOGGLE .054 x .75
DETAIL -27 DOUBLER
IDENTICAL TO -23 DBLR
EXCEPT FOR JOGGLE
DOUBLER
6
5
4


SEAM WELD RIB TO DUCTS
285-0114-5 RIB
ONE AT EA END OF ASSY
285-0114-3 RIB
7 PLACES
(STIFF. ANGLES OMITTED FOR CLARITY)
RIVET PATTERN OF NEXT ASSY REF.
FLARE .03 x 45° TYP OF -9 & -11
SPOTWELD THRU SKIN, DBLR & RIB
CHORD PLANE REF.
SKIN-UPR
DUCT-FWD
DUCT-AFT
DOUBLER
CRIMP
WEB-AFT
ANGLE SEAMWELD TO END RIB
SUBASSY
CONSISTS OF:
-9 & -11 DUCTS, -29 CLIPS,
285-0114-3 & -5 RIBS.
285-0191 REF
CHORD LINE OF OUTBD RIB
CHORD LINE OF INBD RIB
285-0191 SHIELD INSTAL.
DOUBLER
WEB-FWD
SKIN-LWR
26.13 % CHORD REF
AFT FACE FRONT SPAR REF
ASSEMBLE SEGMENT TWISTED ABOUT THIS LINE AS SHOWN
FWD
VIEW LOOKING OUTB'D
TYP. OF EA. END OF ASSEMBLY
FWD FACE REAR SPAR REF.
10. SPOTWELD SPACING .37 C/C APPROX. EXCEPT WHERE OTHERWISE DIMENSIONED.
5. SEE LINES DWG 285-0299 FOR CONTOUR
4. JOGGLE ALLOWANCE 3 TIMES DEPTH
3. ALL BEND RADII .03
2. ALL WELDS PER EPB 11-120
NOTES: UNLESS OTHERWISE SPECIFIED
4
3
2

3

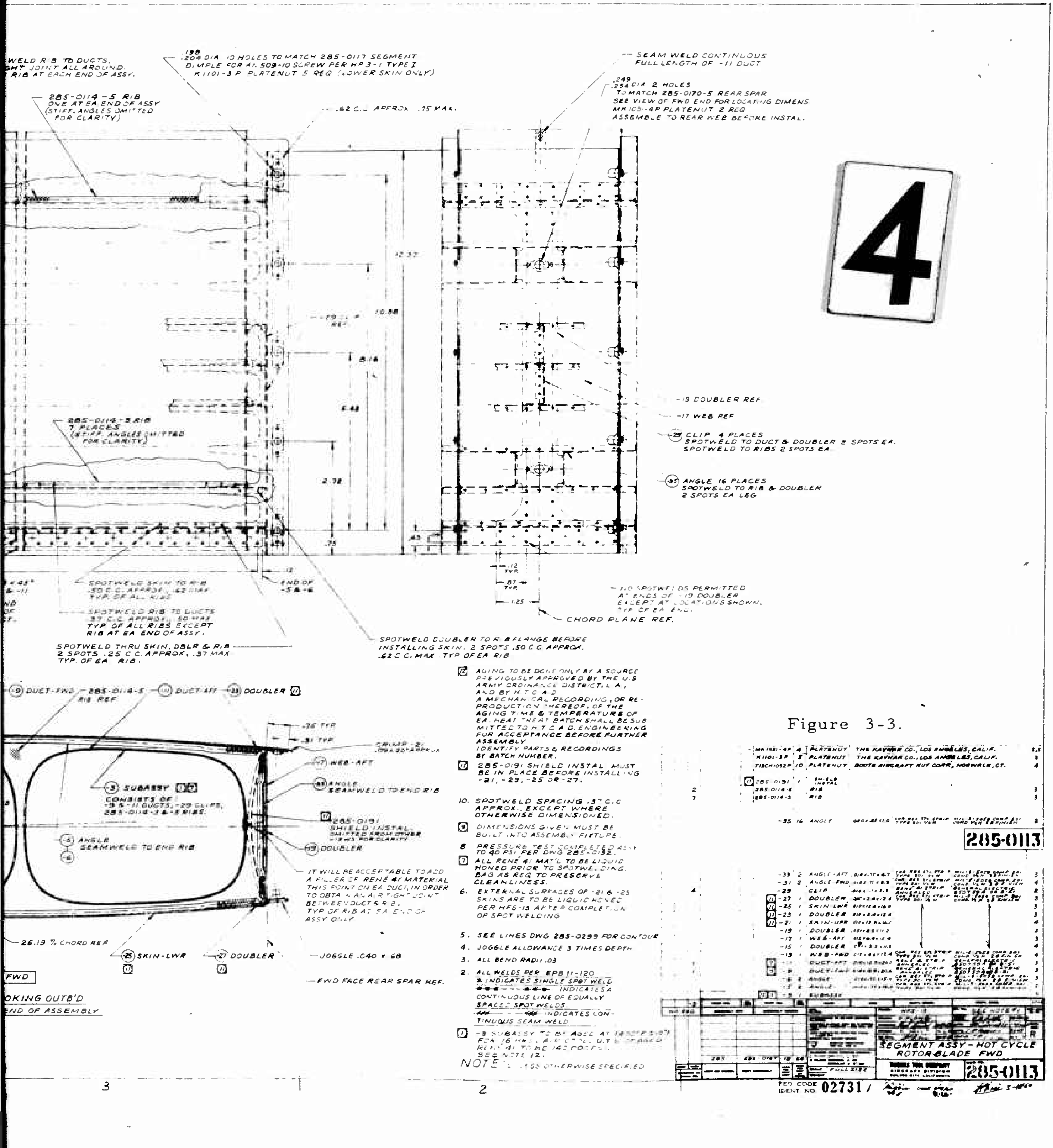

4
SEAM WELD CONTINUOUS FULL LENGTH OF -11 DUCT
285-0114-5 RIB ONE AT EA END OF ASSY (STIFF. ANGLES OMITTED FOR CLARITY)
285-0114-3 RIB 7 PLACES (STIFF. ANGLES OMITTED FOR CLARITY)
-19 DOUBLER REF
-17 WEB REF
CLIP 4 PLACES SPOTWELD TO DUCT & DOUBLER 3 SPOTS EA. SPOTWELD TO RIBS 2 SPOTS EA
ANGLE 16 PLACES SPOTWELD TO RIB & DOUBLER 2 SPOTS EA LEG
CHORD PLANE REF.
SPOTWELD THRU SKIN, DBLR & RIB 2 SPOTS .25 C.C. APPROX., .37 MAX TYP. OF EA RIB.
SPOTWELD DOUBLER TO RIB FLANGE BEFORE INSTALLING SKIN. 2 SPOTS .50 C.C APPROX. .62 C.C. MAX. TYP OF EA RIB
DUCT-FWD
285-0114-5 RIB REF
DUCT-AFT
DOUBLER
WEB-AFT
SUBASSY
ANGLE SEAMWELD TO END RIB
DOUBLER
26.13 % CHORD REF
SKIN-LWR
DOUBLER
JOGGLE .040 X .68
FWD FACE REAR SPAR REF.
FWD
LOOKING OUTB'D END OF ASSEMBLY
10. SPOTWELD SPACING .37 C.C APPROX., EXCEPT WHERE OTHERWISE DIMENSIONED.
5. SEE LINES DWG 285-0299 FOR CONTOUR
4. JOGGLE ALLOWANCE 3 TIMES DEPTH
3. ALL BEND RADII .03
2. ALL WELDS PER EPS 11-120
NOTES UNLESS OTHERWISE SPECIFIED
SEGMENT ASSY - HOT CYCLE ROTOR BLADE FWD
285-0113
FED CODE IDENT NO 02731
3
2

Figure 3-3.

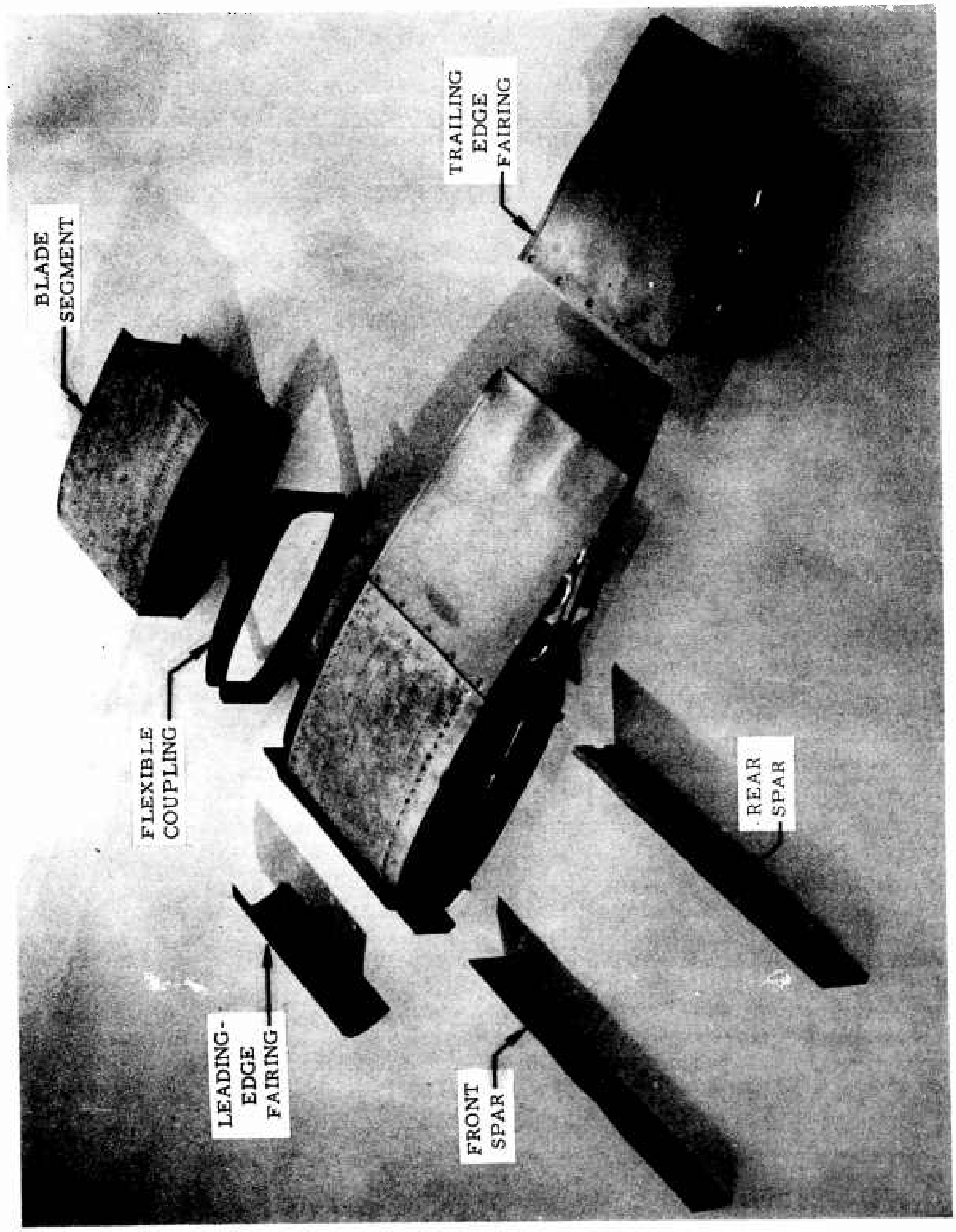
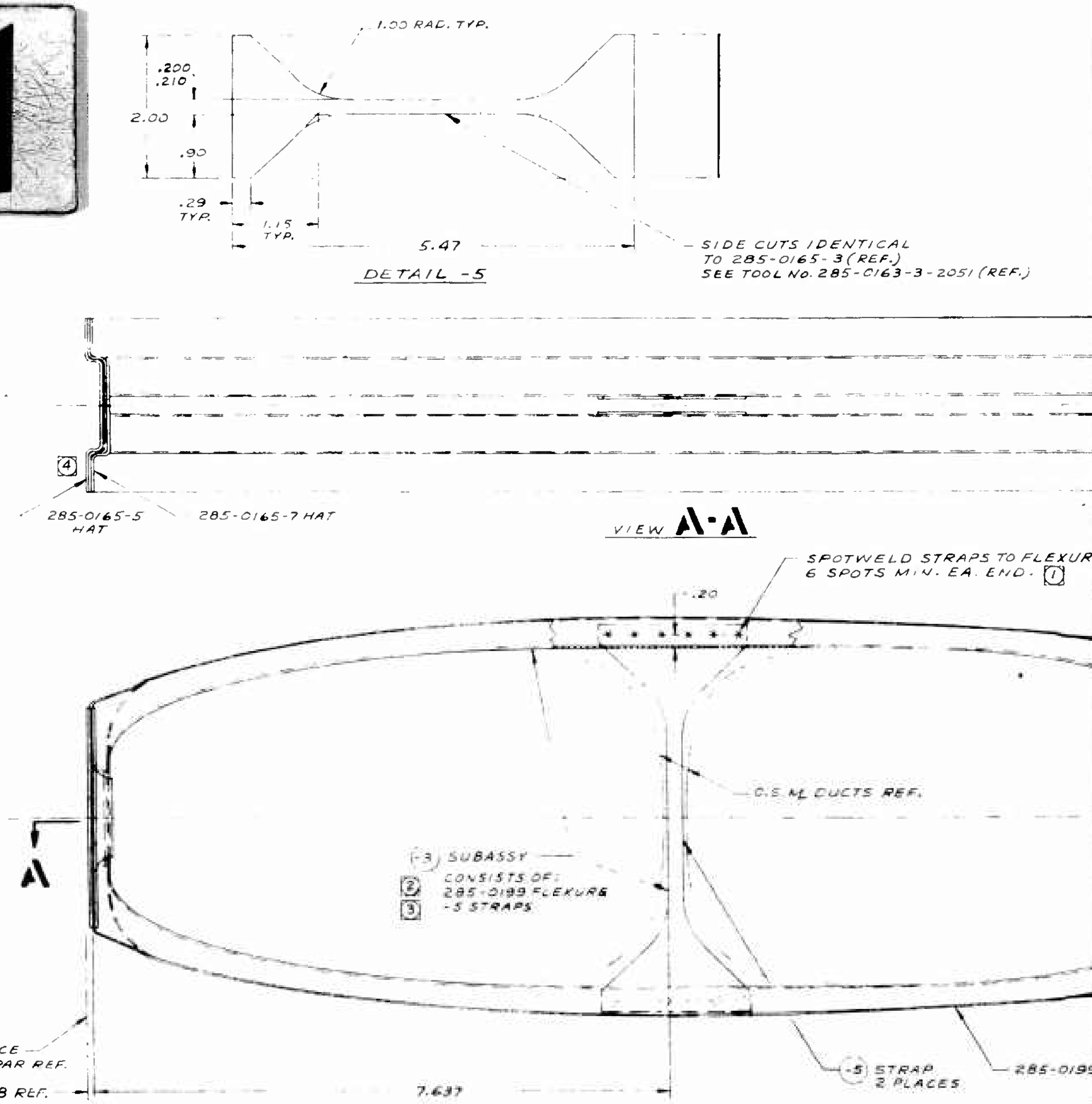


Figure 3-4. Blade Assembly - Exploded View (Photo)

1



3 -3 SUB ASSY TO BE GLASS PEENED
OR IN AREAS WHERE STRAPS AT
PEEN WITH GLASS BEADS TO AN
DETERMINED BY ALMEN A GAG
TEST STRIP .024 THICK.
PEENING TO BE PERFORMED BY
VENDOR TO RETAIN TEST STRIP
ABOVE REQUIREMENTS.
SEQUENCE OF PEENING SURFAC
TO PRODUCE MINIMUM DISTOR

5 OPERATIONS OF NOTES No. 1 THRU No. 4 TO BE PERFORMED IN SEQUENCE NUMBERED.

4 CEMENT 285-0165-5 THRU -9 HATS TO -3 SUB ASSY WITH
A THIN COAT OF SILASTIC RTV 601 PER EPB 5-101.
HATS TO BE COATED OVER ENTIRE FACE ON SIDE NEXT TO FLEXURE.

2 AGE -3 SUBASSY AT 1300°F FOR

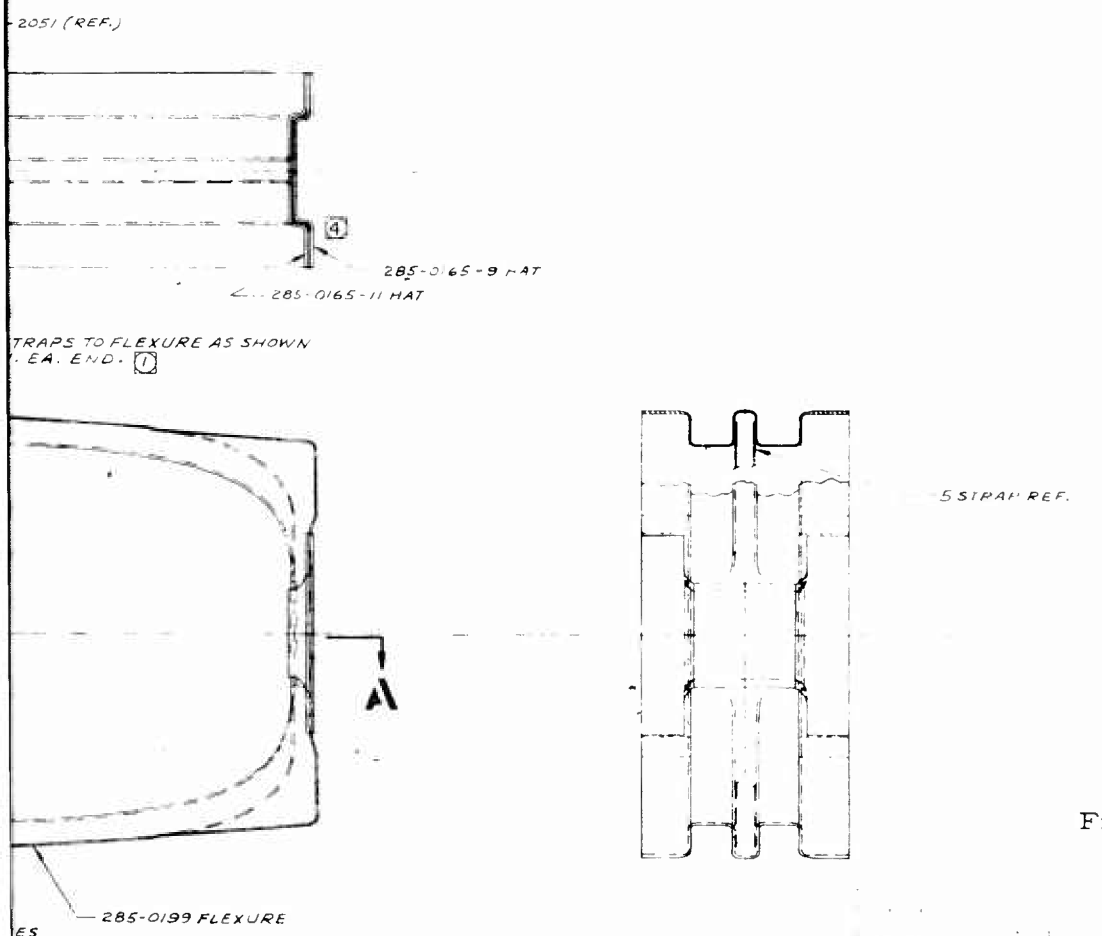
1 SPOTWELD -5 STRAPS TO 285-0199

NOTE: UNLESS OTHERWISE SPE

DIETERICH POST CLEARPRINT 1000H

DO NOT SCALE

LET	EFFECTIVE ON SERIAL NO FROM	THRU	E O NO.	DESCRIPTION OF CHANGE	DRWN BY	CHKD	APPR	DATE



2

285-0203

Figure 3-5.

BE GLASS PEENED ALL OVER, EXCEPT ON -5 STRAPS
HERE STRAPS ATTACH TO FLEXURE.
ASS BEADS TO AN INTENSITY OF .006-.009 AS
BY ALMEN A GAGE ON A 2024-T ALUM. ALLOY
24 THICK.
E PERFORMED BY METAL IMPROVEMENTS CO., L.A.
AIN TEST STRIP AND TO CERTIFY PEENING TO
EMENTS.
PEENING SURFACES TO BE PROGRAMMED SO AS
INIMUM DISTORTION OF PART.

Y AT 1300°F FOR 20 HOURS. AIR COOL.

RAPS TO 285-0199 FLEXURE PER EPB 11-120.

OTHERWISE SPECIFIED

-3	PART NO	NO REQ	NAME	SIZE	MAT'L DESCR	MAT'L SPEC
	285-0195-11	1	HAT			
	-9	1				
	-7	1				
	285-0195-5	1	HAT			
1	285-0199		FLEXURE			
2	-5		STRAP	.020 x 2.0 x 5.5	INCONEL-X SHEET	AMS 5542
2 3	-3	1	SUB-ASSY			
SUB-ASSY REQ	ASSEMBLY SHOWN					

UNIT OR MODEL	NEXT ASSEMBLY	REQ PER NEXT ASSY	REQ PER UNIT OR MODEL
285	285-0167	16	48

EFFECTIVE ON SERIAL NO: FROM / THRU

DEC. CLASS
DIMENSIONS TO BE MET BEFORE PLATING. CORNER RADIUS .005 ON L BORES AND SPOT FACES OF 1.500 DIA OR LESS - .062 RADIUS ON GREATER THAN 1.500 DIA
BREAK ALL SHARP EDGES
SURFACE ROUGHNESS PER MIL STD 10
TOLERANCES UNLESS OTHERWISE SPECIFIED
3 PLACE DECIMAL ± .010
2 PLACE DECIMAL ± .03
ANGULAR ± 0° 30
SCALE FULL SIZE
WEIGHT

FINISH HFS 13
HT TR NOTED 2
DRAWN D. PLOWE
CHECKED
STRESS
PR ENG [signature] 1-31-61
STAFF ENGR
APPD
APPD
MAT'L LS
DWG SIZE D

COUPLING ASSY-WROUGHT

HUGHES TOOL COMPANY
AIRCRAFT DIVISION
CULVER CITY, CALIFORNIA

DWG NO 285-0203

FED CODE IDENT NO 02731

VELLUM D SIZE FORM 8488

FIGURE 3-6

TYPICAL BLADE SEGMENT JOINT

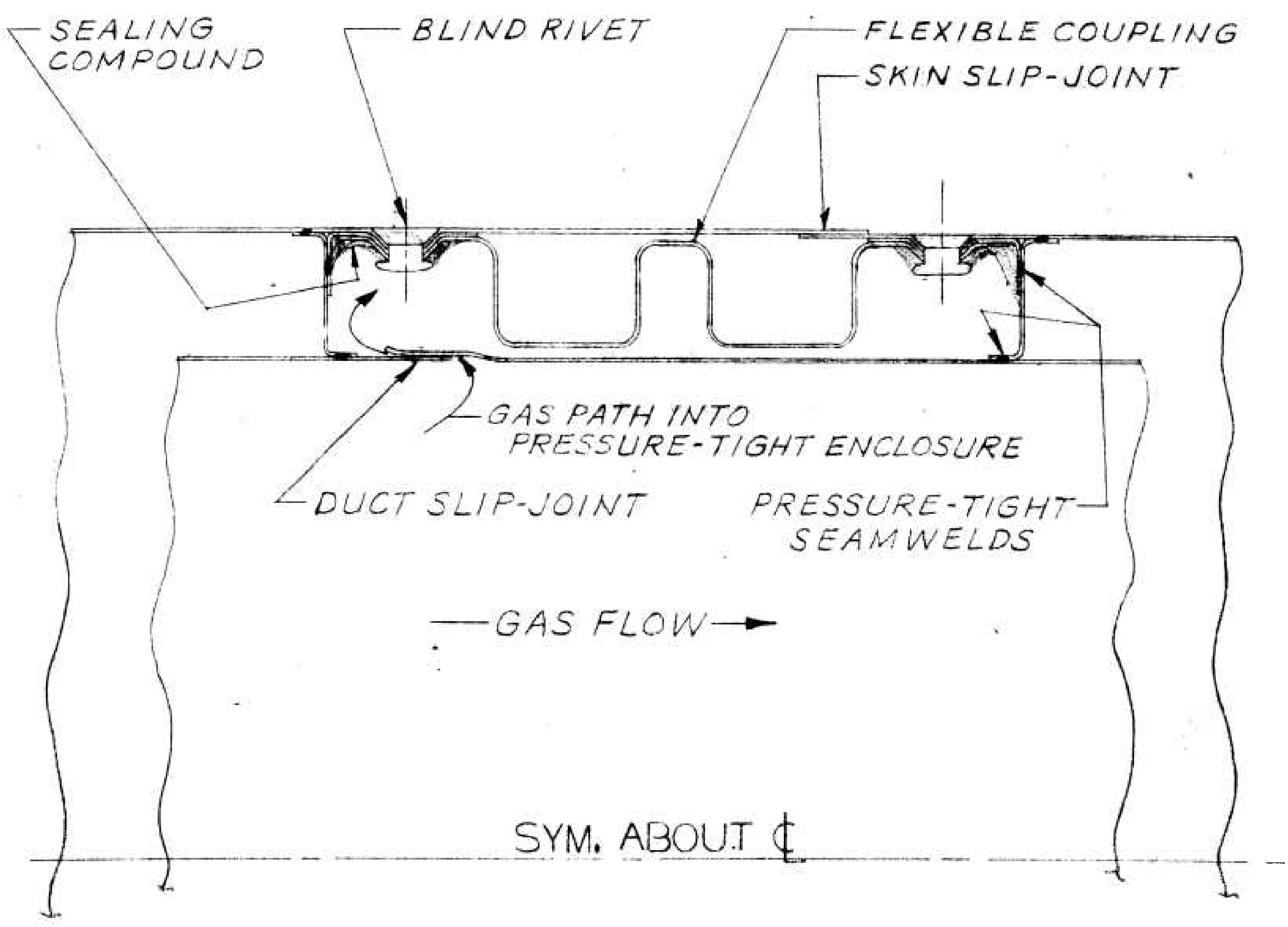
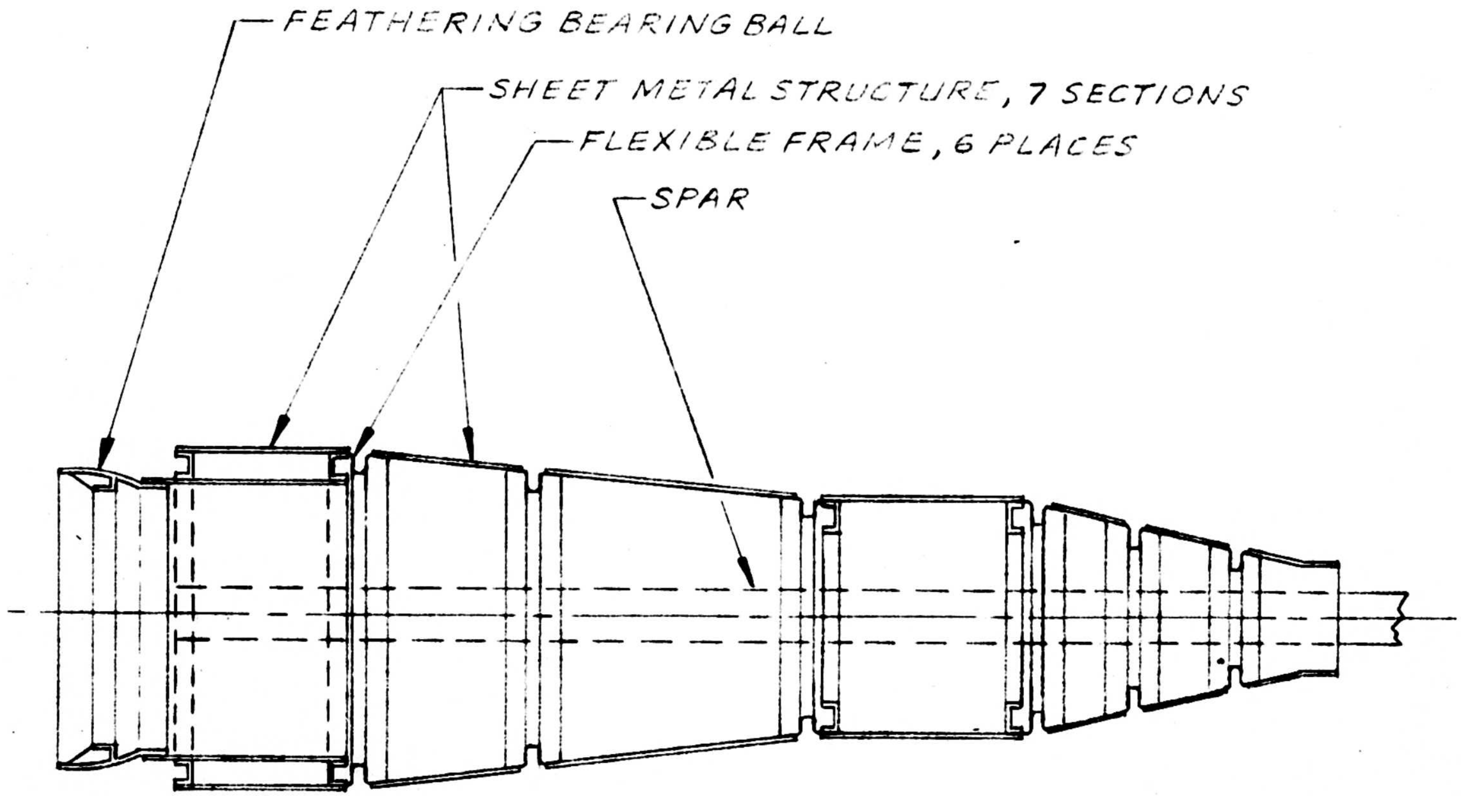


Figure 3-7. Tip Cascade - Outboard View (Photo)

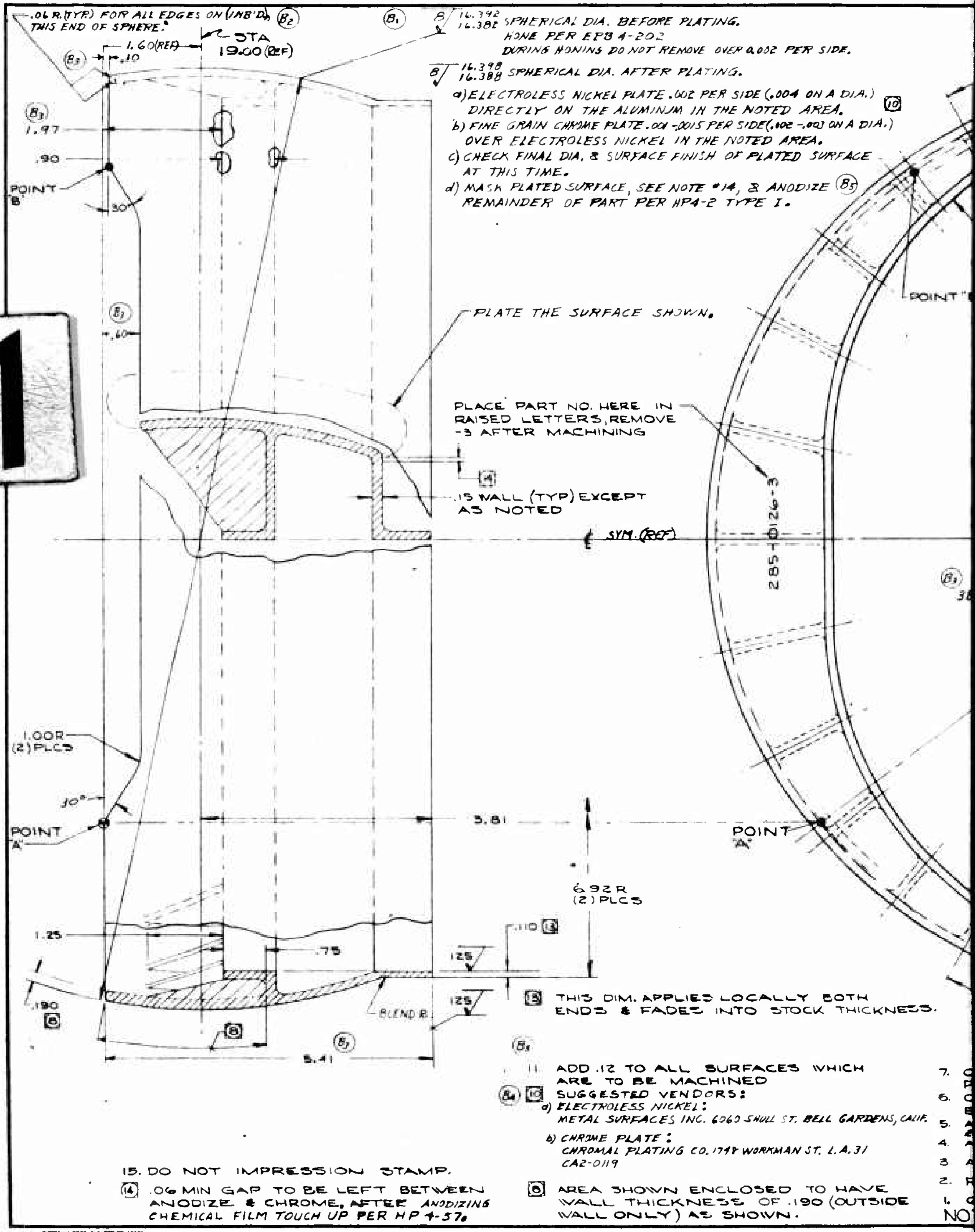
Figure 3-8. Tip Cascade - Inboard View (Photo)



SCHEMATIC SECTIONAL VIEW - BLADE ROOT STRUCTURE

FIG. 3-9

1


.06 R.(TYP.) FOR ALL EDGES ON (INB'D) THIS END OF SPHERE.
STA 19.00 (REF)
1.60 (REF)
.10
1.97
.90
POINT "B"
30°
.60
16.392 / 16.382 SPHERICAL DIA. BEFORE PLATING.
HONE PER EPB 4-202
DURING HONING DO NOT REMOVE OVER 0.002 PER SIDE.
16.398 / 16.388 SPHERICAL DIA. AFTER PLATING.
a) ELECTROLESS NICKEL PLATE .002 PER SIDE (.004 ON A DIA.) DIRECTLY ON THE ALUMINUM IN THE NOTED AREA.
b) FINE GRAIN CHROME PLATE .001-.0015 PER SIDE (.002-.003 ON A DIA.) OVER ELECTROLESS NICKEL IN THE NOTED AREA.
c) CHECK FINAL DIA. & SURFACE FINISH OF PLATED SURFACE AT THIS TIME.
d) MASK PLATED SURFACE, SEE NOTE #14, & ANODIZE REMAINDER OF PART PER HP4-2 TYPE I.
PLATE THE SURFACE SHOWN.
PLACE PART NO. HERE IN RAISED LETTERS, REMOVE -3 AFTER MACHINING
285-0126-3
POINT "B"
.15 WALL (TYP) EXCEPT AS NOTED
SYM. (REF)
1.00R (2) PLCS
30°
POINT "A"
5.81
POINT "A"
6.92 R (2) PLCS
.110
1.25
.75
.125
.125
.190
BLEND R.
5.41
THIS DIM. APPLIES LOCALLY BOTH ENDS & FADES INTO STOCK THICKNESS.
11. ADD .12 TO ALL SURFACES WHICH ARE TO BE MACHINED
10 SUGGESTED VENDORS:
a) ELECTROLESS NICKEL: METAL SURFACES INC. 6060 SHULL ST. BELL GARDENS, CALIF.
b) CHROME PLATE: CHROMAL PLATING CO. 1748 WORKMAN ST. L.A. 31 CA2-0119
15. DO NOT IMPRESSION STAMP.
14 .06 MIN GAP TO BE LEFT BETWEEN ANODIZE & CHROME, AFTER ANODIZING CHEMICAL FILM TOUCH UP PER HP 4-57.
8 AREA SHOWN ENCLOSED TO HAVE WALL THICKNESS OF .190 (OUTSIDE WALL ONLY) AS SHOWN.
7.
6.
5.
4.
3
2.
1.
NO

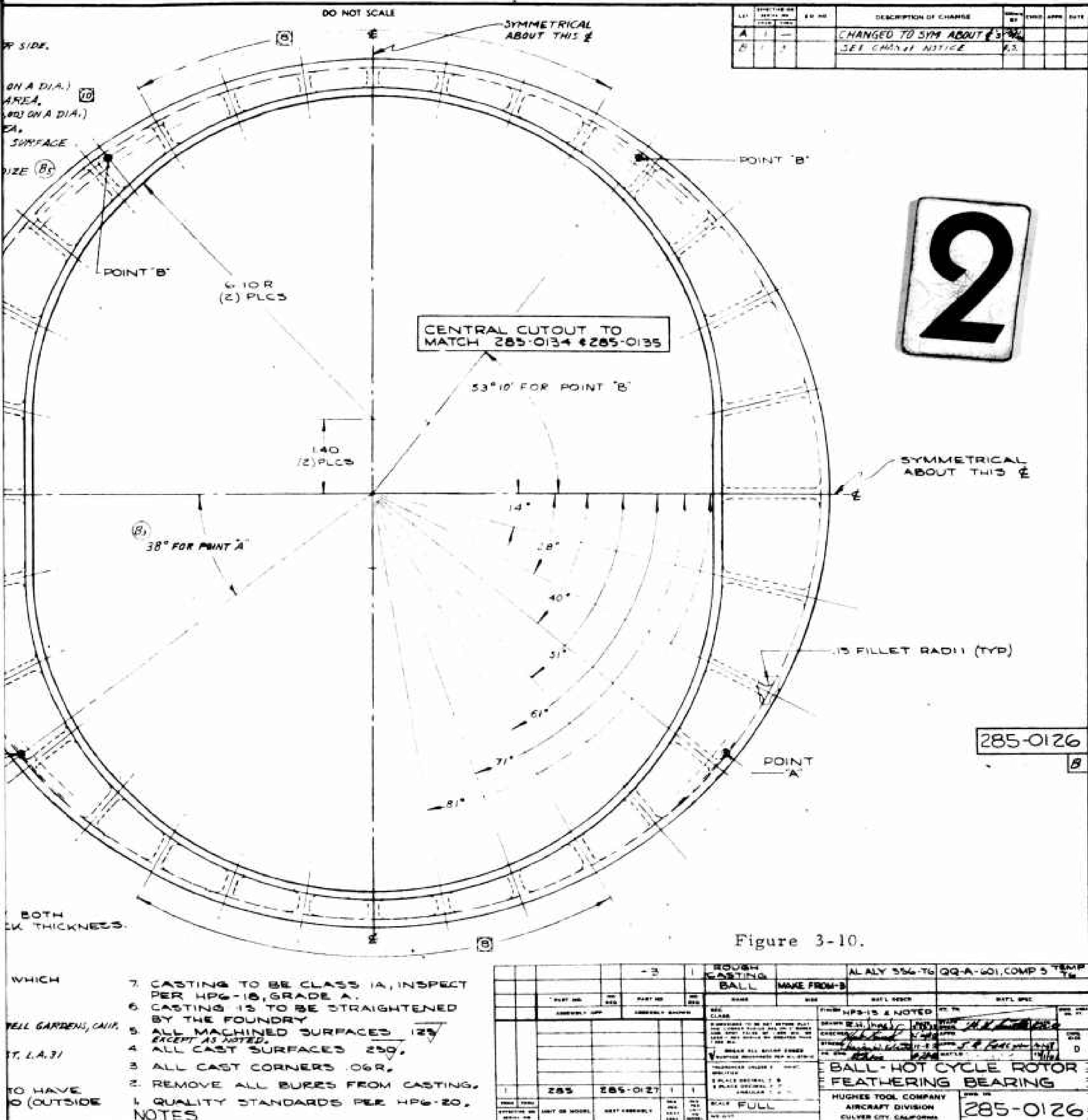
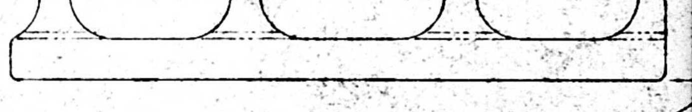
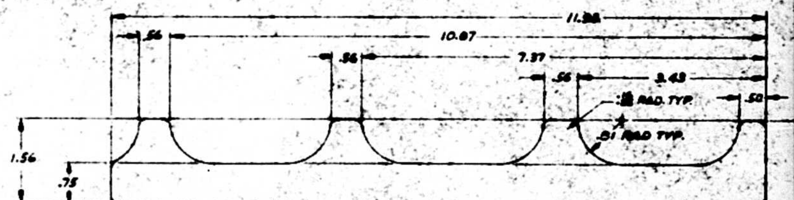

DO NOT SCALE
SYMMETRICAL ABOUT THIS ℄
CHANGED TO SYM ABOUT ℄
SEE CHANGE NOTICE
POINT "B"
POINT "B"
6.10 R (2) PLCS
CENTRAL CUTOUT TO MATCH 285-0134 & 285-0135
53° 10' FOR POINT "B"
1.40 (2) PLCS
SYMMETRICAL ABOUT THIS ℄
14°
28°
40°
51°
61°
71°
81°
38° FOR POINT "A"
.15 FILLET RADII (TYP)
285-0126
POINT "A"
7. CASTING TO BE CLASS IA, INSPECT PER HP6-18, GRADE A.
6. CASTING IS TO BE STRAIGHTENED BY THE FOUNDRY
5. ALL MACHINED SURFACES 125 EXCEPT AS NOTED.
4. ALL CAST SURFACES 250.
3. ALL CAST CORNERS .06 R.
2. REMOVE ALL BURRS FROM CASTING.
1. QUALITY STANDARDS PER HP6-20.
NOTES
ROUGH CASTING
BALL
MAKE FROM -3
AL ALY 356-T6
QQ-A-601, COMP 5
HP3-15 & NOTED
FULL
BALL - HOT CYCLE ROTOR FEATHERING BEARING
HUGHES TOOL COMPANY
AIRCRAFT DIVISION
CULVER CITY, CALIFORNIA
285-0126
285
285-0127
FED. CODE IDENT NO 02731

Figure 3-10.

1

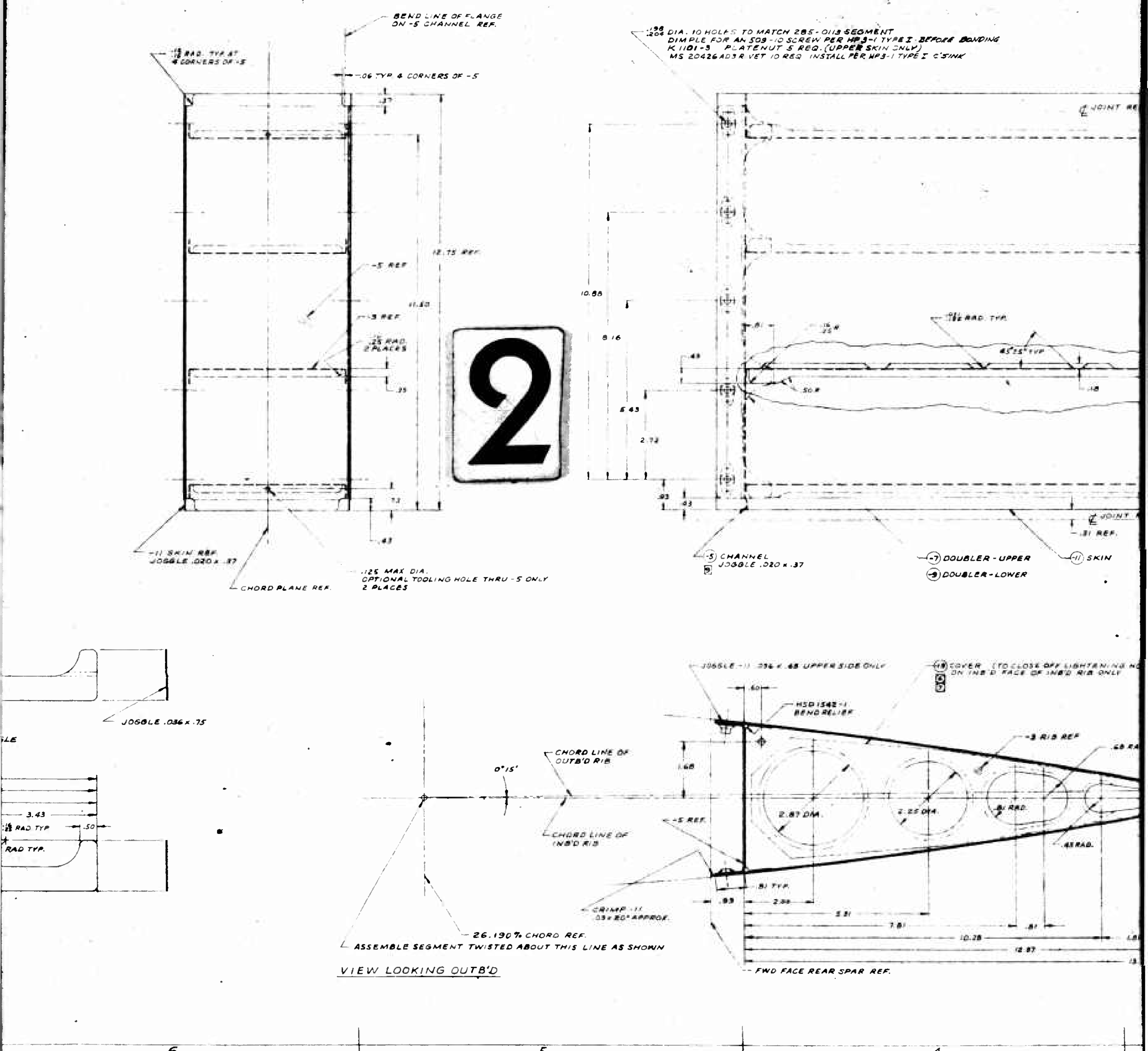


DETAIL -7 DOUBLER
IDENTICAL TO -9 EXCEPT FOR JOGGLE

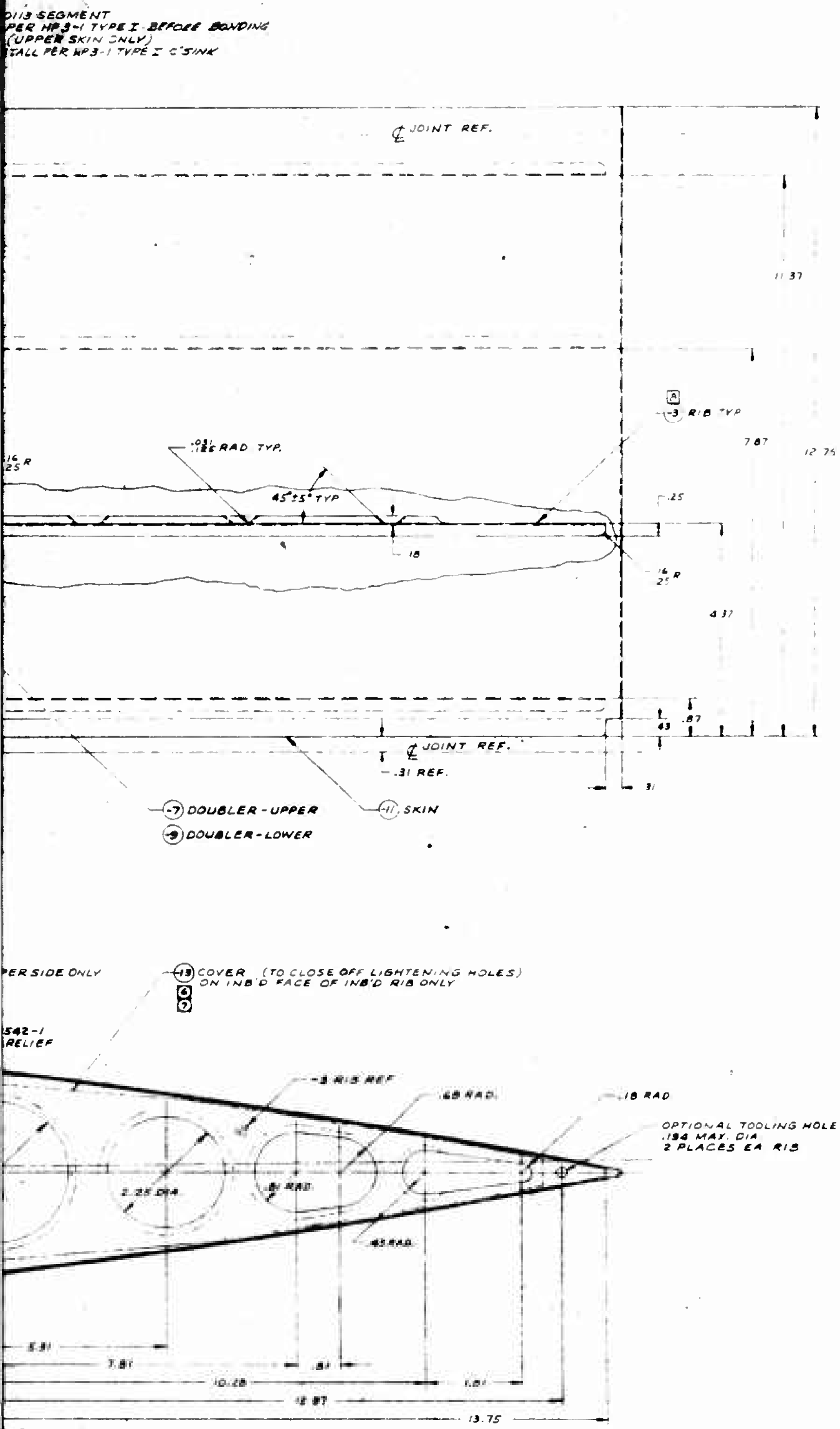


DETAIL -9 DOUBLER

8 7



BEND LINE OF FLANGE ON -5 CHANNEL REF.
RAD. TYP AT 4 CORNERS OF -5
.06 TYP 4 CORNERS OF -5
12.75 REF.
11.50
-5 REF
-3 REF
.25 RAD. 2 PLACES
-11 SKIN REF. JOGGLE .020 x .37
CHORD PLANE REF.
.125 MAX DIA. OPTIONAL TOOLING HOLE THRU -5 ONLY 2 PLACES
2
DIA. 10 HOLES TO MATCH 285-0113 SEGMENT
DIMPLE FOR AN 509-10 SCREW PER HP3-1 TYPE I BEFORE BONDING
K 1101-3 PLATENUT 5 REQ. (UPPER SKIN ONLY)
MS 20426AD3 RIVET 10 REQ INSTALL PER HP3-1 TYPE I C'SINK
JOINT REF
10.88
8.16
5.43
2.72
45°±5° TYP
-5 CHANNEL JOGGLE .020 x .37
-7 DOUBLER - UPPER
-9 DOUBLER - LOWER
-11 SKIN
.31 REF.
JOGGLE .036 x .75
3.43
RAD TYP.
JOGGLE -11 .036 x .68 UPPER SIDE ONLY
COVER (TO CLOSE OFF LIGHTENING HOLE ON INB'D FACE OF INB'D RIB ONLY
HSD 1542-1 BEND RELIEF
-3 RIB REF
CHORD LINE OF OUTB'D RIB
CHORD LINE OF INB'D RIB
0°15'
1.68
2.87 DIA.
2.25 DIA.
.81 RAD.
.43 RAD.
-5 REF.
.81 TYP.
CRIMP -11 .03 x 80° APPROX.
26.190% CHORD REF.
ASSEMBLE SEGMENT TWISTED ABOUT THIS LINE AS SHOWN
VIEW LOOKING OUTB'D
2.88
5.31
7.81
10.28
12.87
FWD FACE REAR SPAR REF.
6
5
4



3

9 -5 CHANNEL. ANODIZE PER HP4-2 TYPE II, AND DYE BLACK MATTE.
8 FLANGES MUST BE IN DIRECTIONS SHOWN.
7 ANODIZE -3, -7, -9 & -11, (NOT -13) PER HP4-2
6 ATTACH -13 COVER TO RIB WITH 1221 BT CEMENT PER HP16-1 MAY BE OBTAINED FROM PRODUCTS RESEARCH CO. LOS ANGELES, CALIFORNIA.

5 ALL BEND RADII .03
4. ALL 2024-T3 MATL TO BE AGED TO T81 PER HP1-2. AGING TIME TO BE 9½ HOURS AT 370-380°F
3. FOR CONTOURS SEE LINES DWG 285-0299
2 ALL BEND RADII .03.
1 BOND PER EPB 16-114 USING NARMCO METLBOND 4021, ALL FAYING SURFACES EXCEPT PLATE NUTS. METLBOND MAY BE OBTAINED FROM NARMCO RESINS & COATINGS CO COSTA MESA, CALIFORNIA

NOTE UNLESS OTHERWISE SPECIFIED

4 3 2

F

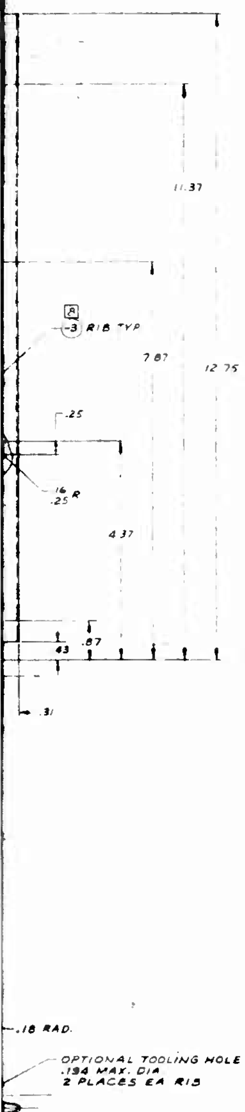


Figure 3-11.

285-0117

9. -5 CHANNEL, ANODIZE PER HP4-2 TYPE II, AND DYE BLACK MATTE.
8. FLANGES MUST BE IN DIRECTIONS SHOWN.
7. ANODIZE -3, -7, -9 & -11 (NOT -13) PER HP4-2
6. ATTACH -13 COVER TO RIB WITH 1221 BT CEMENT PER HP16-1 MAY BE OBTAINED FROM PRODUCTS RESEARCH CO. LOS ANGELES, CALIFORNIA.
5. ALL BEND RADII .03
4. ALL 2024-T3 MATL TO BE AGED TO T81 PER HP1-2. AGING TIME TO BE 9½ HOURS AT 370-380°F
3. FOR CONTOURS SEE LINES DWG 285-0299.
2. ALL BEND RADII .03.
1. BOND PER EPE 16-114 [illegible], NARMCO METLBOND 3021, ALL FAYING SURFACES EXCEPT PLATE NUTS. METLBOND MAY BE OBTAINED FROM NARMCO RESINS & COATINGS CO COSTA MESA, CALIFORNIA

NOTE UNLESS OTHERWISE SPECIFIED

-13	1	COVER	.003x4x13	ALUM FOIL	MIL-A-148A or COMM'L	4
[illegible]	10	RIVET				4
[illegible]	5	PLATENUT	RAYNAR CO. LOS ANGELES, CALIF.			4
-11	1	SKIN	[illegible]	2024-T3	QQ-A-362 TEMP T3	4
-9	1	DOUBLER	[illegible]			4
-7	1	DOUBLER	[illegible]			4
-5	1	CHANNEL	[illegible]			5
-3	8	RIB	[illegible]	2024-T3	QQ-A-362 TEMP T3	3

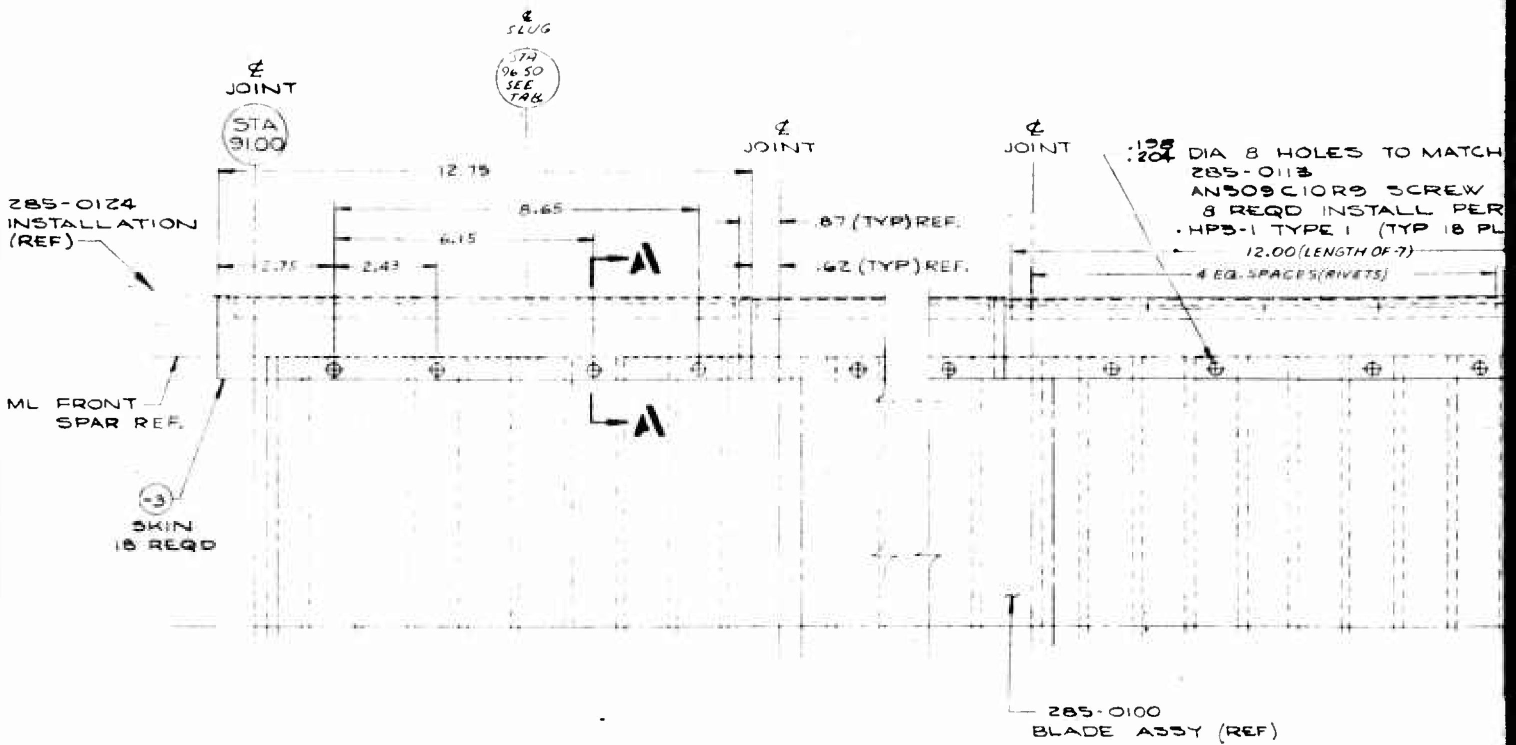
SEGMENT ASSY - HOT CYCLE ROTOR BLADE - AFT

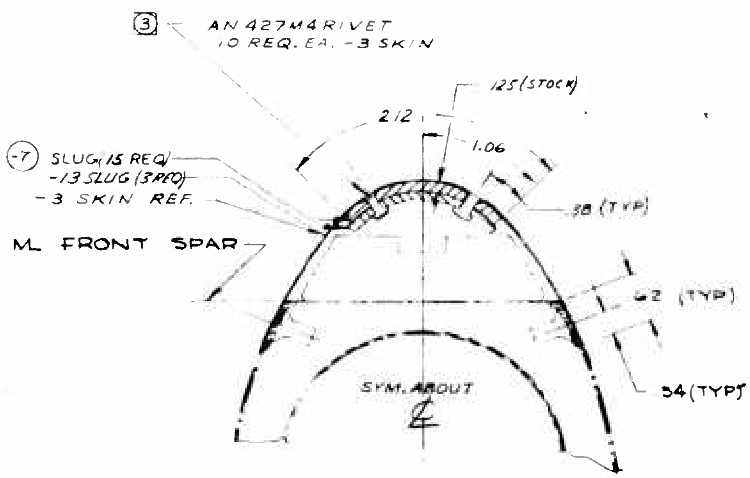
SCALE FULL SIZE

285-0117

02731

3 2





SECT A-A
FULL SIZE

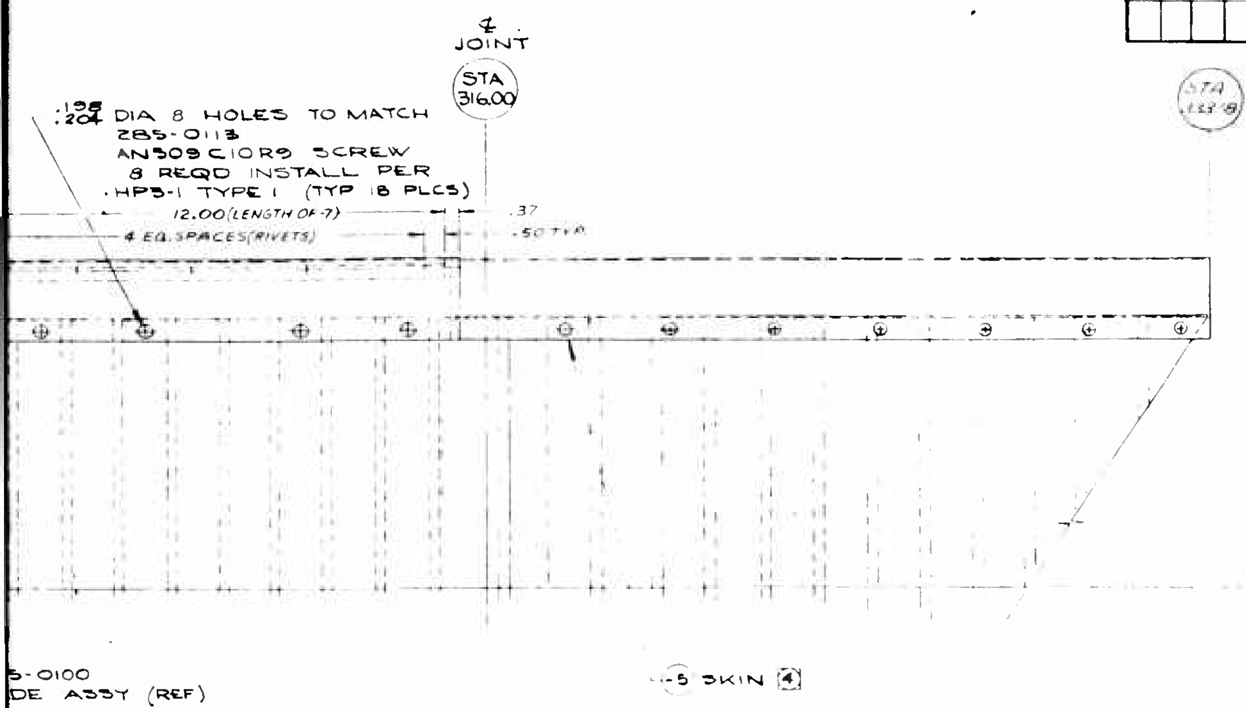
TABULATION FOR SLUG LOCATION		
STA ℄ SLUG	SLUG DASH NO	NO REQ
96.50	-7 & -13	
109.00	|	1 OF EACH
121.50	-7 & -13	
134.00	-7 & -9	
146.50	|	1 OF EACH
159.00	-7 & -9	
171.50	-7 & -11	
184.00	|	1 OF EACH
196.50	-7 & -11	
209.00	-11	
221.50	|	2 OF -11
234.00	-11	
246.50	-7 & -15	
259.00	|	1 OF EACH
271.50	-7 & -15	
284.00	-7	
296.50	|	1 OF -7
309.00	-7	

1

6 DO NOT IMPRESSION S
5 TAG FOR IDENTIFICATION
4 DETAILS OF -5 SKIN W
DRAWING UPON COMPL
285-0171 TIP ASSY.
3 INSTALL RIVETS PER HP
2 -3 & -5 TO BE U
1. FOR CONTOUR S
285-0299
NOTES UNLESS OTHE

DO NOT SCALE

LET	EFFECTIVE ON SERIAL NO FROM	THRU	E O NO	DESCRIPTION OF CHANGE	DRWN BY	CHKD	APPR	DATE
4				See Change Notice	AH			



ON FOR SLUG LOCATION	
SLUG DASH NO	NO REQ
-7 E-13 / -7 E-13	1 OF EACH
-7 E-9 / -7 C-9	1 OF EACH
-7 E-11 / -7 E-11	1 OF EACH
-11 / -11	2 OF -11
-7 E-15 / -7 E-15	1 OF EACH
-7 / -7	1 OF -7

285-0123
4

Figure 3-12.

PART NO	NO REQ	NAME	SIZE	MAT'L ORDER	MAT'L SPEC
AN427M4	180	RIVETS			
AN509C10R9	152	SCREW			
-15	3	SLUG	.032 x 3/8 x 12.00	301 CRES SHT	MIL-S-5059 COMP 301 ANNEALED 2D FINISH
-13	3		.080 x 3/8 x 12.00		
-11	9		.080 x 3/8 x 12.00		
-9	3		.100 x 3/8 x 12.00		
-7	15	SLUG	.125 x 3/8 x 12.00	301 CRES SHT	MIL-S-5059 COMP 301 ANNEALED 2D FINISH
-5	1	L.E. SKIN	.020 x 8.75 x 13.00	301 CRES SHT	MIL-S-5059 COMP 301 2B FINISH 1/4 H
-3	18	L.E. SKIN	.080 x 8.00 x 13.00	301 CRES SHT	MIL-S-5059 COMP 301 2B FINISH 1/4 H

6 DO NOT IMPRESSION STAMP
5 TAG FOR IDENTIFICATION
4 DETAILS OF -5 SKIN WILL BE ADDED TO THIS DRAWING UPON COMPLETION OF DESIGN OF 285-0171 TIP ASSY.
3 INSTALL RIVETS PER HP3-1 TYPE I
2 -3 & -5 TO BE LIQUID HONED
1. FOR CONTOUR SEE LINES LAYOUT 285-0299

NOTES UNLESS OTHERWISE SPECIFIED

UNIT OR MODEL	NEXT ASSEMBLY			
285	285-0100	1	3	

FINISH HPS-13 2
DRAWN Z. H.
CHECKED
SCALE 1/2 & NOTED
FAIRING INSTALLATION-HOT CYCLE ROTOR BLADE, NOSE
HUGHES TOOL COMPANY
AIRCRAFT DIVISION
CULVER CITY, CALIFORNIA
SIZE D
DWG NO 285-0123
FED. CODE IDENT NO 02731

SECTION 4

DESIGN OF HUB

4.1 INTRODUCTION

The rotor blade retention and hub structure consists of a free-floating hub supporting three coning blades with converging tension straps tying the blades to the hub. A final assembly drawing of this structure is shown on Figure 4-1. The free-floating hub ties the rotor blades together and transfers their loads to the mast and then through two bearing systems to the supporting trusses. This hub must also provide clearance for the ducts which transfer the gases used in propulsion from below the hub to the three blades. The over-all hub structure also provides support for the control system.

4.2 MATERIAL SELECTION

Both temperatures and clearance restrictions influenced the materials selected for the hub. In some locations the temperatures were sufficiently high as to rule out the use of aluminum alloys. (See Reference 2-2.) In other locations restricted space made steel or other high-strength alloys the logical choice. In general, 4130 or 4340 Chrome Moly Steel was selected for the components except for the lower thrust bearing housing, which is sufficiently cool so that 2014 Aluminum alloy could be used.

4.3 DETAIL DESIGN

4.3.1 Free-Floating Hub Structure

The free-floating hub structure is shown schematically on Figure 4-2. It is composed of a central hexagonal box with two vertical parallel beams extending from the hexagon to support each feathering bearing housing and a pair of blade retention strap shoe fittings. The radial strap loads from the three blades were balanced across the lower surface of the floating hub structure by two parallel plates. Vertical components of the strap loads were transferred from the shoe fittings through the parallel beams to the hexagonal box. Most of these loads are balanced across the box by similar loads from opposing blades. The free-floating hub is universally mounted at the upper end of a rotating mast by a gimbal system. The gimbal clevis transfers all floating hub loads to the mast through the gimbal assembly. (See Figures 4-1 and 4-3.)

4.3.2 Hub Tilt Stop

A hub tilt stop was provided for two separate conditions; one-degree tilt for low rpm and ground handling, and ten degrees for the normal flight operation. Ten degrees allows for flight maneuvers. The one-degree stop condition applies while the rotor is stationary, and until it reached 150 rpm. The one-degree mechanism, shown schematically in Figure 4-4, is an over-center linkage actuated by centrifugal forces on a weighted arm, and incorporates a spring return. Above 150 rpm, the one-degree stop becomes disengaged and the ten-degree condition of tilt is permitted. The ten-degree tilt stop is accomplished by contact of the 285-0584 Mast Plate with the face of the 285-0584 Hub Clevis (Refer to Figure 4-5). As the rotor slows, the one-degree stop again wedges between these two faces at 90 rpm. All hub stop loads are carried between the upper surface of the 285-0529 Hub Clevis and a ten-degree conically surfaced 285-0584 Plate on the mast

4.3.3 Rotor Blade Droop Stop

The blade droop stop is located at the lower inboard face of the blade structure and contacts the lower outboard face of the feathering bearing housing. (See Figure 4-5.) The stop has two Torrington 8NBL2022Y roller bearings with the surfaces ground to a 12-inch radius to provide for misalignment as the rollers contact the hub plate. The hub plate was shaped so that the rollers would stay in contact during the total blade feathering range $+18.6^\circ$ to -21.8° without change in blade coning angle. Droop stop loads from a single blade are transferred through the feathering bearing support ring into the hub where they are balanced by loads from the other two blades, or are transferred by the tilt stop system into the mast.

4.3.4 Mast Support

The rotating mast is supported by two bearing assemblies. (See Figure 4-5.) A lower bearing resists all of the vertical or thrust load while the moments are resisted by radial reactions on this same lower bearing and by an upper bearing which is free to float vertically. The upper bearing outer housing is supported by three radial spokes attached to the mast. The inner housing of this same bearing is attached to a supporting truss attached to the whirl tower or a fuselage. The lower bearing housing is likewise attached to a concentric and similar supporting truss. These two trusses meet at four panel points at the fuselage level. These trusses, shown in Figure 4-1 and 4-5, consist of welded steel tubular structures.

4.3.5 Upper Bearing

The upper bearing is of the cylindrical roller type. (See Detail B, Zone 6, of Figure 4-1, and Figure 4-5.) This bearing was designed to slide freely in a vertical direction, resisting radial loads only. Oil seals were continuous extrusions compounded of silicone rubber. The seals were cut to the proper length, wrapped within the seal housings with ends butted firmly together. Choice of this design was based on its successful application in the XH-17 helicopter previously built and tested by HTC-AD.

Lubrication of the bearing was given particular attention. A circulating oil system was provided in order to insure optimum lubrication and maximum cooling in case bearing temperatures proved to be higher than anticipated. There were four low pressure input ports and four suction discharge ports.

4.3.6 Lower Bearing

The lower support bearing assembly consists of two tapered roller Timken[1] bearings mounted back-to-back. It carries all the vertical load and those radial loads due to moments.

The thrust bearing also has a circulating oil lubrication system, utilizing a part of the same system which lubricates the upper bearing. One pressure input line and four suction return lines are utilized. Oil seals were made of Silicone rubber, bonded to a corrosion resistant steel container, and pressed into the bearing housing. Except for materials, these are standard Garlock seals. (See Figure 4-1, Zone 4, and Figure 4-5.)

4.3.7 Gimbal Installation

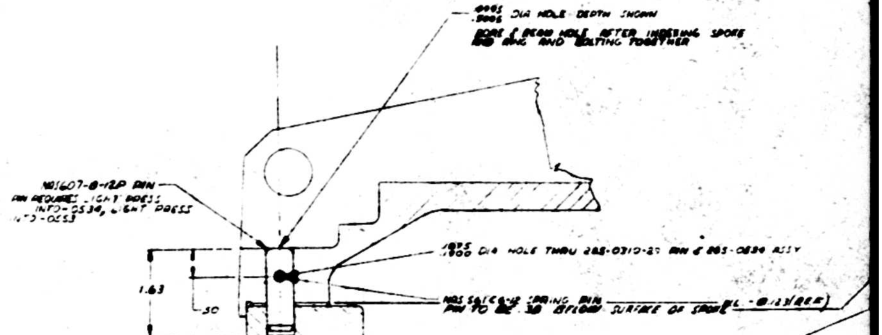
The gimbal installation, Figure 4-1, Zone 4 and Figure 4-3, consists of a gimbal clevis, ring, and mast trunnion. Incorporated in the ring assembly are four number 21309 S. K. F. roller bearings, loaded primarily in a radial direction. These bearings transfer rotor vertical loads and all unbalanced radial loads from the free-floating hub to the rotating mast. They are lubricated with Shell MRAG Grease-ASG-14 with Molybdenum Disulphide added. These bearings showed signs of fretting at an early period during the whirl testing. Shell Oil Company cooperated with HTC-AD by compounding this special lubricant to help alleviate this condition.

1 Tinken Roller Bearing Company, Canton 6, Ohio

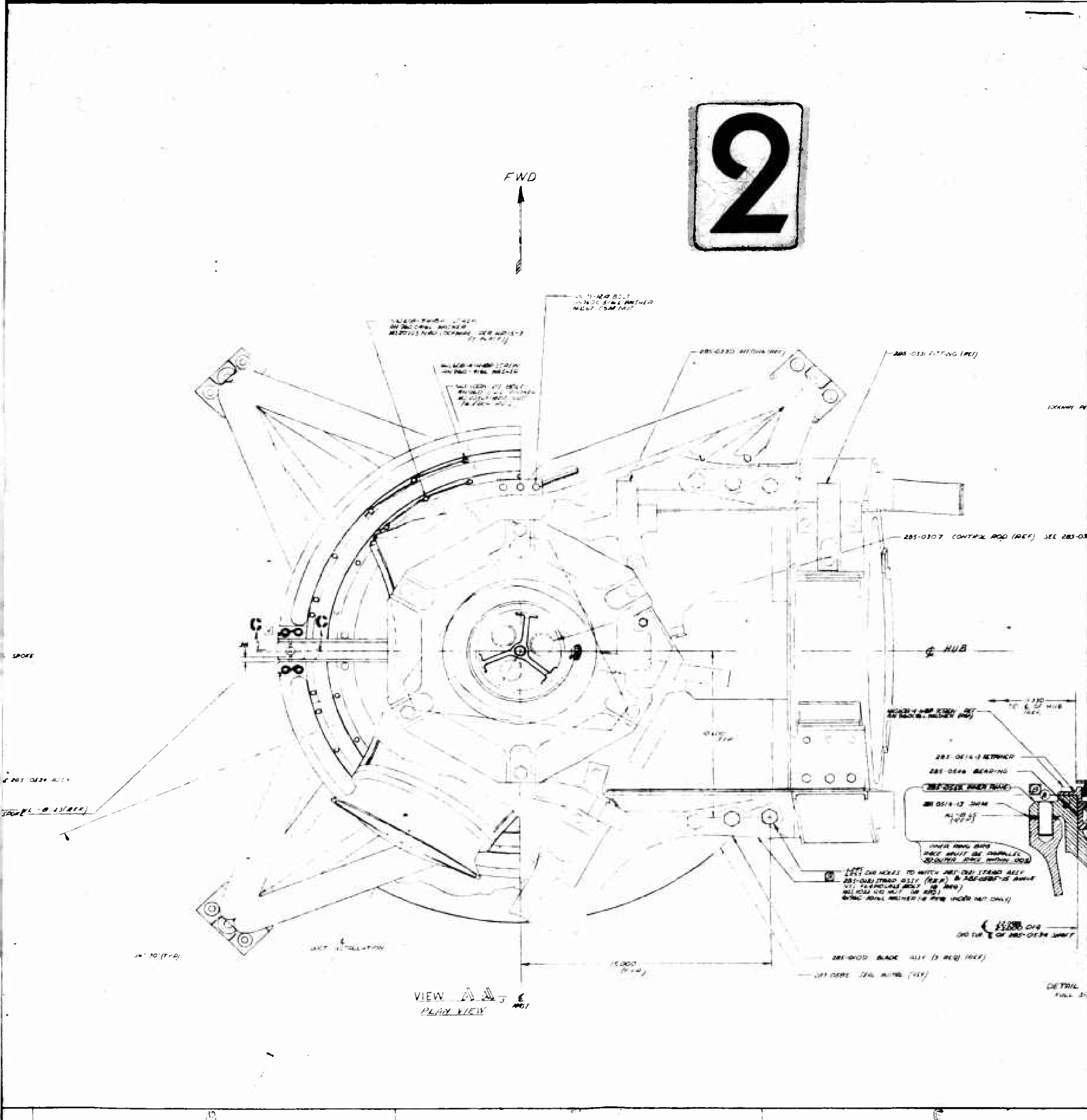
4.3.8 Cooling of Component Parts

A simple, effective method of cooling the various parts of the hub structure was accomplished. Refer to the schematic on Figure 4-6. Because the ducts surround the mast and are located in close proximity to the gimbal assembly, the upper support assembly and the free-floating hub, the temperature of these parts would rise beyond a value which would permit the use of standard bearings and conventional materials without cooling. By using an air seal between the floating hub and the rotating race of the upper bearing, air is drawn through the hub by centrifugal pumping of the rotating blades. This air moves through the hub from three directions (down through the gimbal assembly, up between the mast and duct, and up inside the upper bearing stationary race), and flows outward through the feathering bearings, over the articulate ducts, and is exhausted at approximately blade station 60.00. By this means, the maximum temperature of these important components is maintained at values calculated to be below the following: gimbal installation, 200°F; rotating mast, 500°F; upper bearing support structure, 400°F. In addition, a temperature improvement accrues to other parts where the temperature is less critical.

1

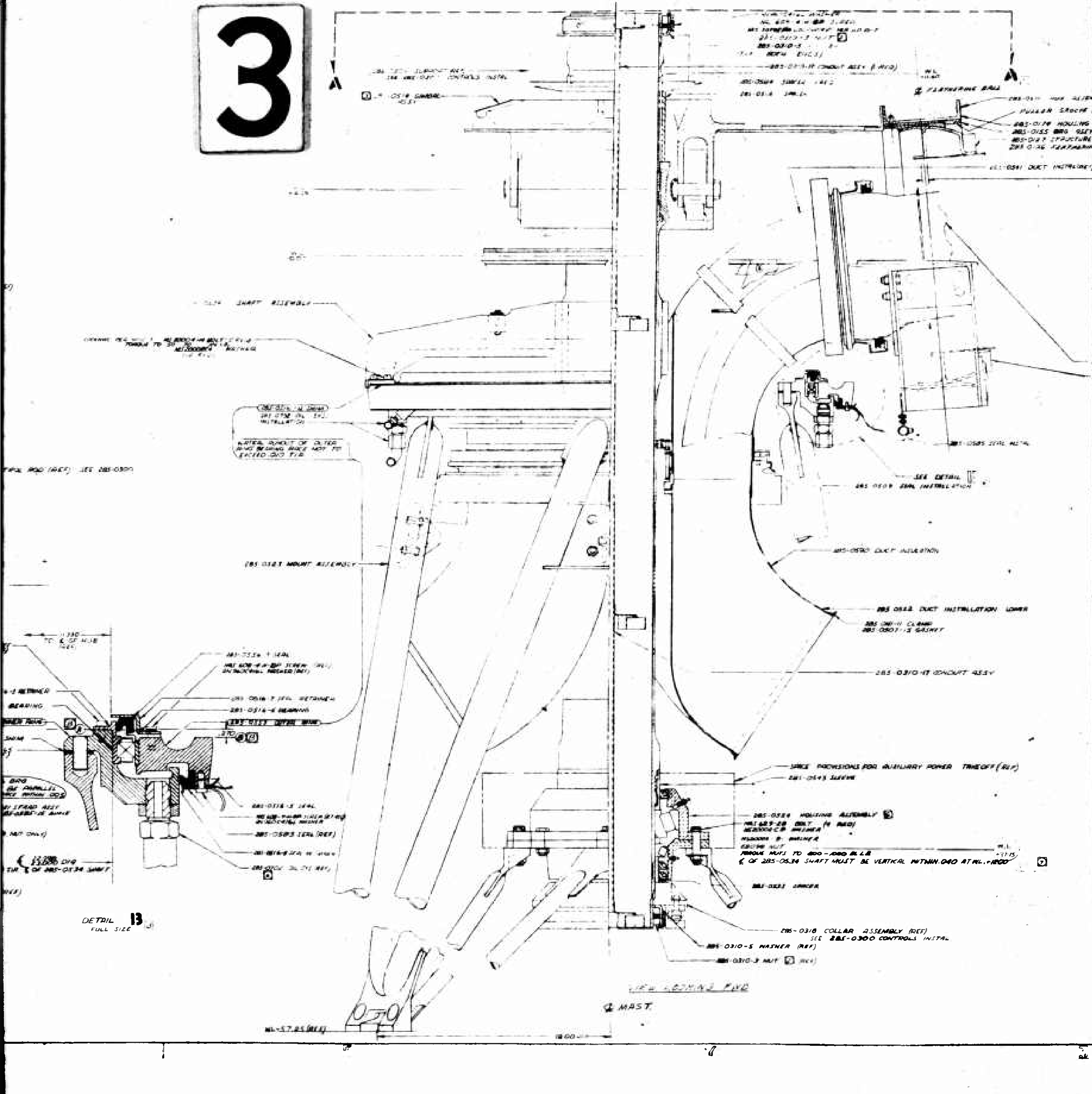


SECTION
FULL SIZE



2
FWD
285-0331 FITTING (REF)
285-0307 CONTROL ROD (REF)
HUB
285-0514-3 RETAINER
285-0546 BEARING
VIEW A-A
PLAN VIEW
DETAIL

3



285-0323 MOUNT ASSEMBLY
285-0310-17 CONDUIT ASSY
285-0590 DUCT INSULATION
285-0522 DUCT INSTALLATION LOWER
285-0585 SEAL INSTAL
SEE DETAIL
285-0509 SEAL INSTALLATION
SPACE PROVISIONS FOR AUXILIARY POWER TAKEOFF (REF)
285-0534 HOUSING ASSEMBLY
285-0318 COLLAR ASSEMBLY (REF)
SEE 285-0300 CONTROLS INSTAL
285-0310-5 WASHER (REF)
285-0310-3 NUT (REF)
VIEW LOOKING FWD
℄ MAST
DETAIL 13
FULL SIZE

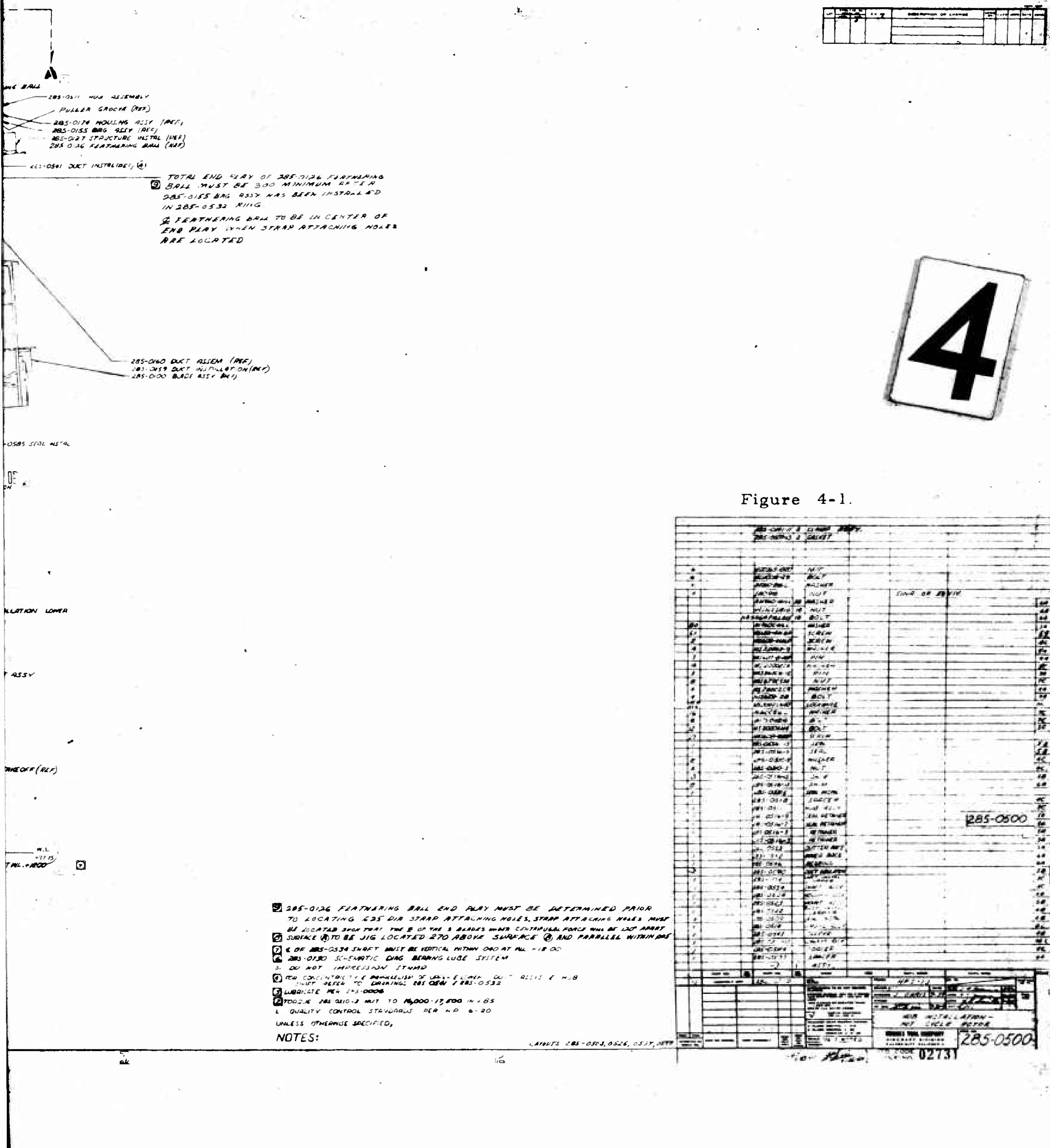
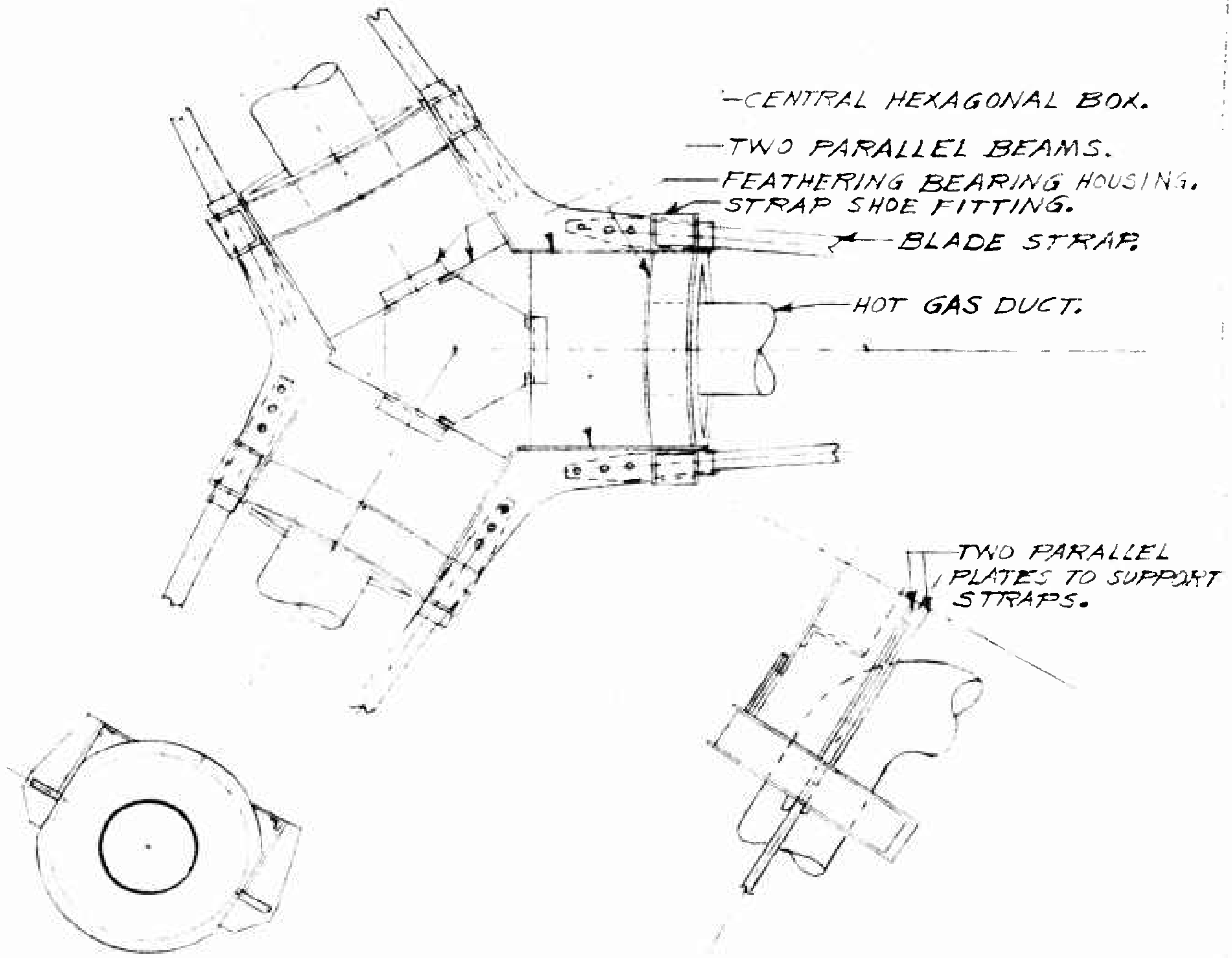

285-0511 HUB ASSEMBLY
PULLER GROOVE (REF)
285-0174 HOUSING ASSY (REF)
285-0155 BRG ASSY (REF)
285-0127 STRUCTURE INSTAL (REF)
285-0126 FEATHERING BALL (REF)
TOTAL END PLAY OF 285-0126 FEATHERING BALL MUST BE .300 MINIMUM AFTER 285-0155 BRG ASSY HAS BEEN INSTALLED IN 285-0532 RING
℄ FEATHERING BALL TO BE IN CENTER OF END PLAY WHEN STRAP ATTACHING HOLES ARE LOCATED
285-0160 DUCT ASSEM (REF)
285-0100 BLADE ASSY (REF)
4
285-0500
9 285-0126 FEATHERING BALL END PLAY MUST BE DETERMINED PRIOR TO LOCATING .625 DIA STRAP ATTACHING HOLES. STRAP ATTACHING HOLES MUST BE LOCATED SUCH THAT THE ℄ OF THE 3 BLADES UNDER CENTRIFUGAL FORCE WILL BE 120° APART
8 SURFACE (A) TO BE JIG LOCATED 270 ABOVE SURFACE (B) AND PARALLEL WITHIN .005
7 ℄ OF 285-0534 SHAFT MUST BE VERTICAL WITHIN .040 AT WL +18.00
6 285-0730 SCHEMATIC DIAG BEARING LUBE SYSTEM
5. DO NOT IMPRESSION STAMP
4 FOR CONCENTRICITY & PARALLELISM OF
SHIFT REFER TO DRAWINGS 285 0540 & 285-0522
3 LUBRICATE PER 285-0006
2 TORQUE 285 0510-3 NUT TO 15,000-17,500 IN LBS
1. QUALITY CONTROL STANDARDS PER HP 6-20
UNLESS OTHERWISE SPECIFIED,
NOTES:
HUB INSTALLATION - HOT CYCLE ROTOR
285-0500
02731

Figure 4-1.

FIGURE 4-2 BASIC FREE-FLOATING HUB STRUCTURE.



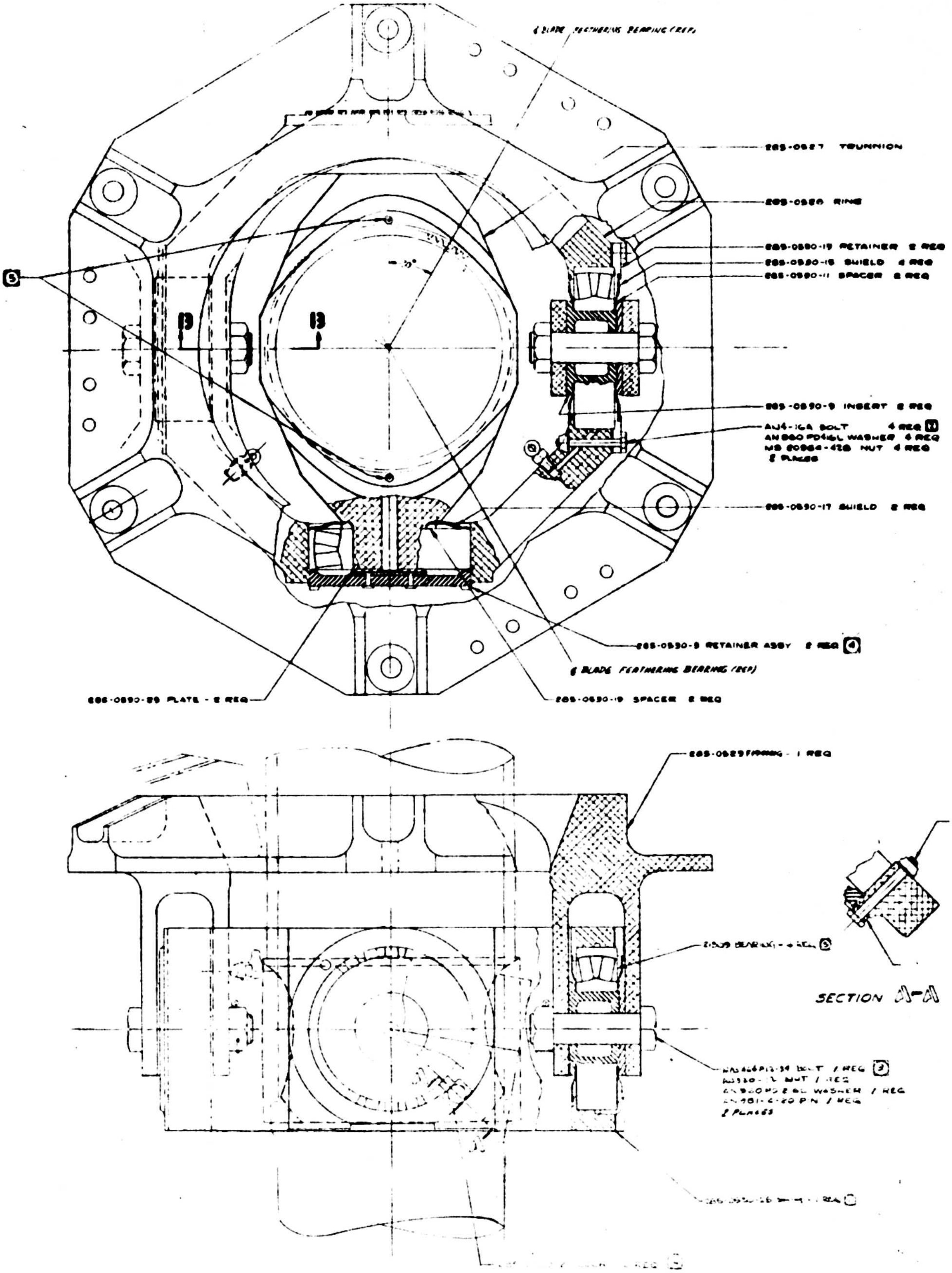


Figure 4-3. Hub Gimbal

FIGURE 4-4 HUB TILT STOP

TILT STOPS ARE LOCATED AT THE TOP OF THE HUB IN THREE PLACES AS SHOWN BELOW.

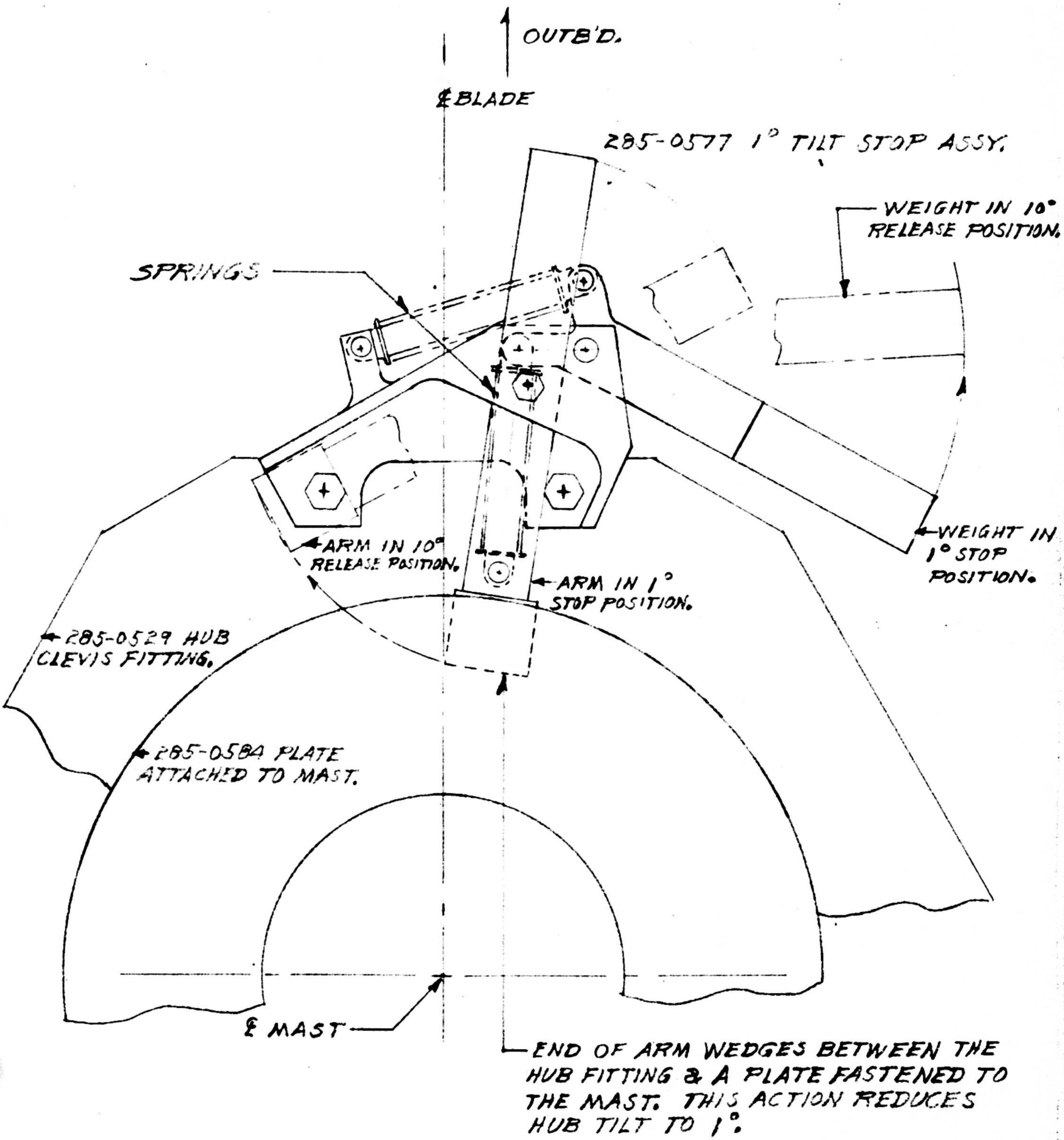


FIGURE 4-5 MAST SUPPORT

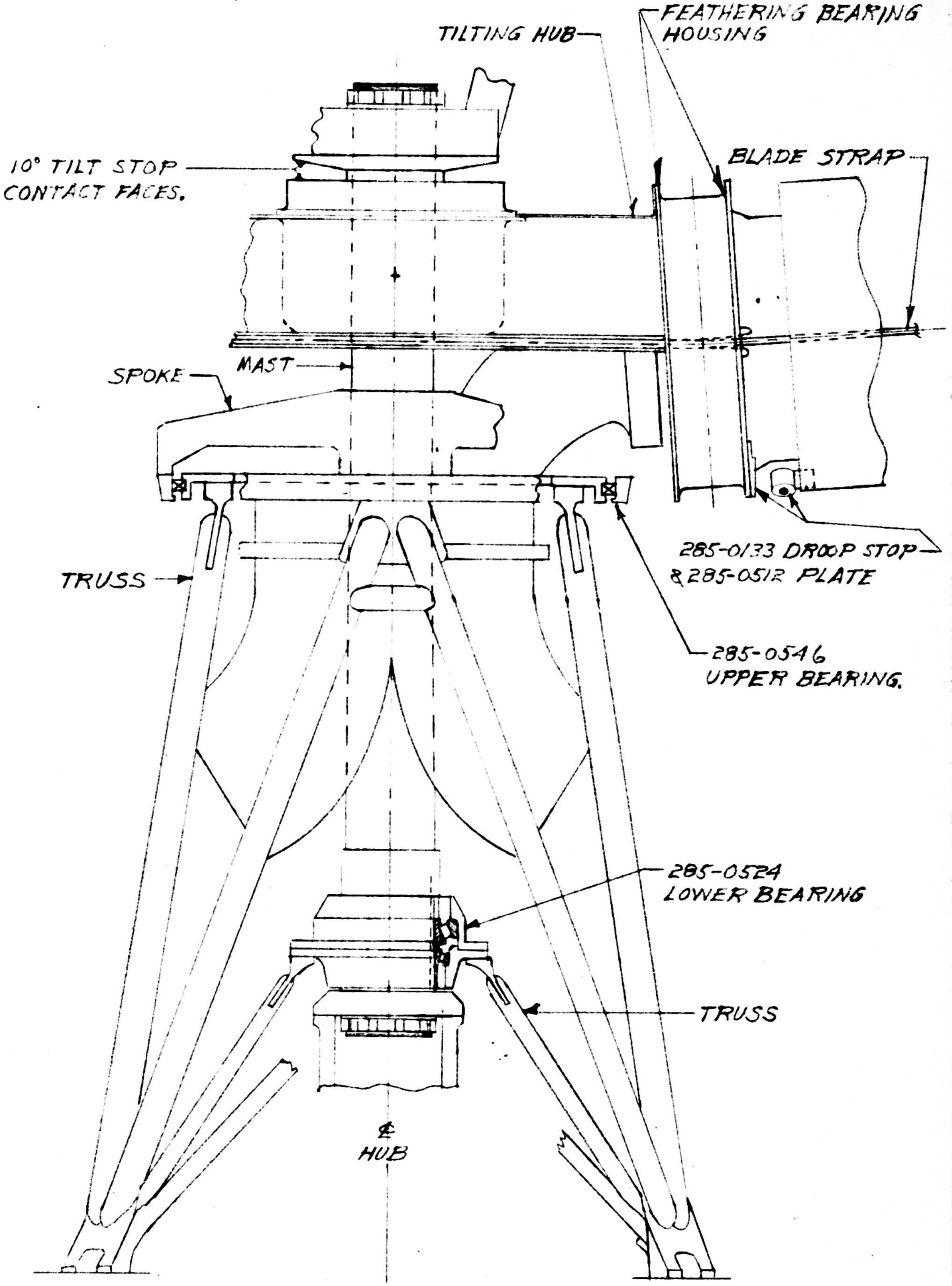
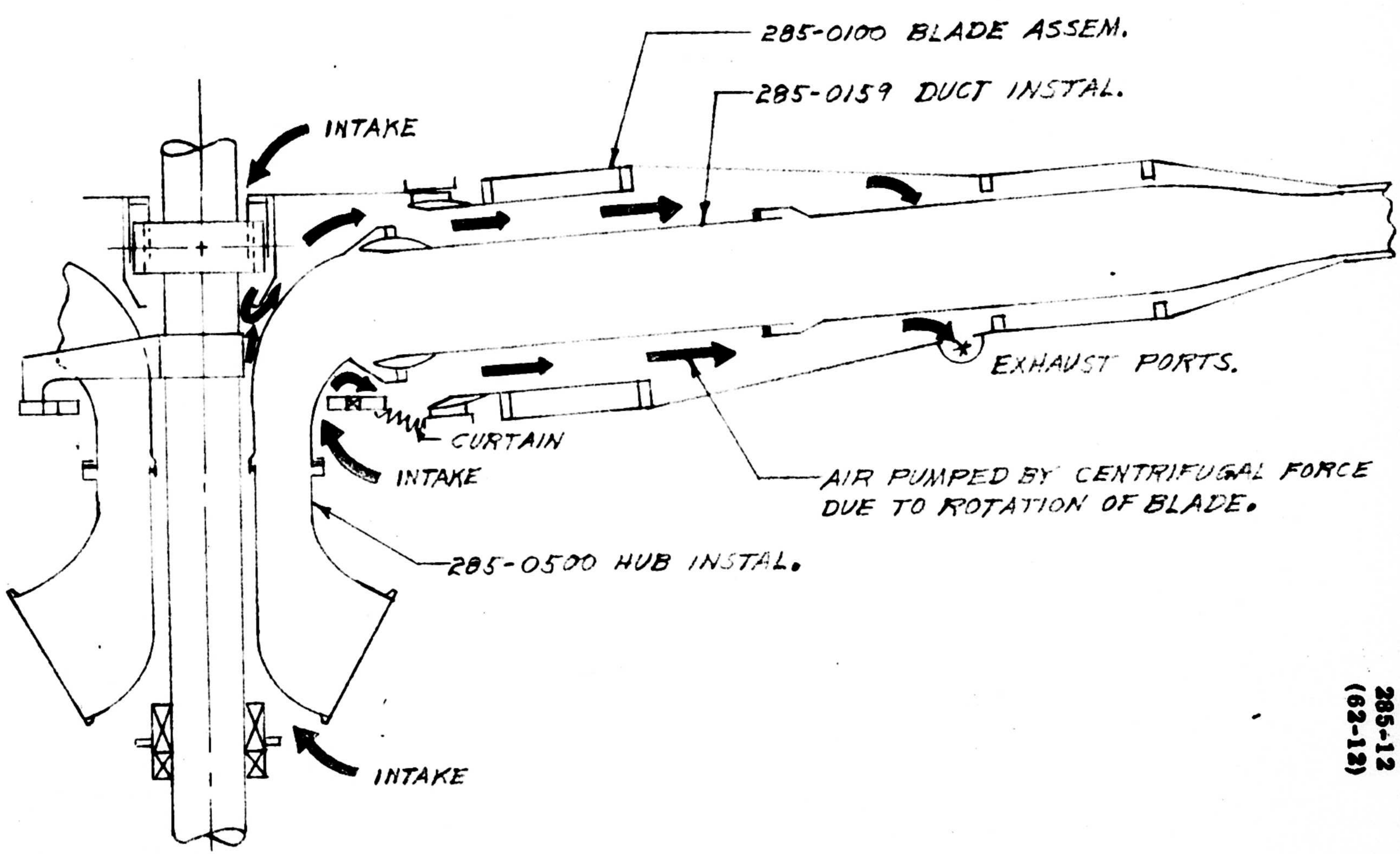


FIGURE 4-6 COOLING OF HUB & ROTOR BLADE



SECTION 5

DUCTS

5.1 INTRODUCTION

Basically, the purpose of the ducts is to receive gas from the engines and to provide an avenue for it through the free-floating hub, then along the entire length of the blade and out the tip cascades. A schematic of the duct system is shown on Figure 5-1. Two main problems in connection with design of a duct system were that of material selection and seal design in a system which had to operate without conventional lubricants. Both problems were complicated by the high temperatures (1200°F) and relative motions imposed by hub tilt, blade coning, and thermal expansion.

Each seal presented a different problem, since the relative motions between the sections to be sealed, and the duct temperatures, varied at each location. This Contractor consulted numerous vendors with long experience regarding seals and high temperature materials who cooperated in the design. A number of tests were performed in order to determine suitability of materials and seal configurations.

5.2 DUCT DESIGN AND MATERIAL SELECTION

5.2.1 Hub Ducts

The hub two-branch stationary and the three-branch rotating ducts are designed to be fabricated of type 347 corrosion resistant steel with the basic ducts formed on a drop hammer. Simplicity was maintained by the utilization of two rugged side stiffeners, all elements of which could be hand-formed. Fusion welding was employed to fabricate these assemblies.

5.2.2 Blade Ducts

From the articulate duct inboard seal to station 60.50 the duct is circular in shape, of type 321 or 347 corrosion resistant alloy. This metal is readily available, forms easily and is weldable.

From station 60.50 to 91.00 a transition exists which starts with a circular shape at the inboard end and progresses to two roughly-elliptical openings at the outboard end. Due to the non-circular shape, a relatively high strength alloy, Inconel "X," is used for this duct.

The duct from station 15.50 to 42.50 is articulated to allow for hub float and blade coning. At the inboard end of this duct a mechanism for

allowing freedom of motion in two directions is required. In a coning direction this motion is $+24^{\circ}$ to -16°, while in a chordwise direction the motion is $\pm 2^{\circ}$. To allow for these motions a gimbal using Fabroid[1] bearings for the coning motion and flexures for the chordwise motion are used. At the outboard end of the duct, freedom of motion is again required and the design of this point is discussed in a later paragraph.

5.2.3 Hub and Blade Duct Joints

Duct sections are clamped together as shown on schematic Figure 5-2. Each joint is identical in section and consists of lightweight machined flanges, an asbestos gasket, and a V-band clamp. Gasket material is 0.093 thick, number J-M 60 Johns-Manville asbestos[2]. This is a long-fibered asbestos material designed for high pressures and temperatures. The V-band clamps[3] are fabricated of 19-9 DL and A-286 corrosion resistant alloys.

5.3 SEAL DESIGN

5.3.1 Carbon Seals

Carbon, with no supplemental lubrication, is used as the sealing material in the hub duct region. These seals are shown schematically on Figure 5-2. The carbon used has been impregnated to improve its operation at high operating temperatures. Available data indicated that three carbon materials, from three different manufacturers, were qually satisfactory for use on the duct seals. All three carbon materials: Purebon #56HT[4], Graphitar #2490[5], and National #CDJ-83[6] were, therefore, permitted by HTC-AD and all were used by the sub-contracting manufacturers.

In the hub duct outer seal, two rows of carbon segments are held against the rotating duct by two garter springs. A row of compression springs hold the carbon segments against the surface of the seal housing. Gas pressure aids the springs in maintaining a tight seal. During the whirl test, to make installation easier, the twenty-four compression springs were replaced by one wave spring.

1 Mircoo-Precision Division of Micromatic Hone Company, Los Angeles, California
2 Johns-Manville, New York 16, New York
3 Marmon Division of Aeroquip Corporation, Los Angeles, California
4 Pure Carbon Company, St. Marys, Pennsylvania
5 The United States Graphite Company, Saginaw, Michigan
6 National Carbon Company, Cleveland, Ohio

The hub duct inner seal was changed from a labyrinth to a face seal when the gas temperature and pressure were raised to their present values[1].

This inner seal utilizes a carbon face seal at the rotating face, and two rows of carbon segments supported by two garter springs and a wave spring for the static seal, as shown in the sketch of Figure 5-2. The seal allows ±0.090 inch of relative movement between the upper (rotating) and the lower (stationary) duct without separation occuring at the face seal.

The articulate duct inboard seal is approximately the same as the hub duct outer seal described above. (See schematic in Figure 5-1.)

5.3.2 Articulate Duct Outboard All Metal Seal

At the articulate duct outboard seal a different set of conditions exist. The seal at this point must seal against axial movement (due to hub float and blade coning), rotation (due to blade feathering), misalignment (due to hub float and blade coning), and side impact (due to a change from small positive to negative blade coning angles). A more malleable material than carbon is required here because of the necessity to carry side load and to accept reversal of loading.

Three distinct types of seals were designed and tested before one was found that would function satisfactorily under all conditons. The first seal consisted of segments of titanium carbide compound used in the same manner as the carbon segments in the hub area. The cylinder was type 347 corrosion - resistant alloy, flame plated with tungsten carbide. This seal depended on very close fits of all components, and when tested showed two major faults; the cylinder warped out of round 0.090 inch on a diameter and the segments warped slightly in all directions. The net result was an unacceptable leakage rate.

The next seal was a single lip type seal with a lip of Rene' 41 alloy riding on the same tungsten carbide coated cylinder. Both the lip and the cylinder were coated with Electrofilm #1000X[2] to reduce friction. This seal functioned well for small misalignment angles. Above ±3°, however, friction increased rapidly until at approximately 6° misalignment the lip would lock on the cylinder.

1 Refer to Modification 11 of the contract
2 Electrofilm, Inc., North Hollywood, California

The third seal design proved satisfactory. This consisted of a nest of three slotted lip laminations riding on the same tungsten carbide coated cylinder. Each lamination is formed from 0.010 Rene' 41 alloy. Slots in the laminations are staggered to eliminate continuous paths through which gas could leak. In addition to the three laminated lips, two overload leaves (0.020 thick) were added at the top and bottom only. All lip laminations and the cylinder are coated with Electrofilm 1000X to reduce friction. A sketch of the final design is shown in Figure 5-3.

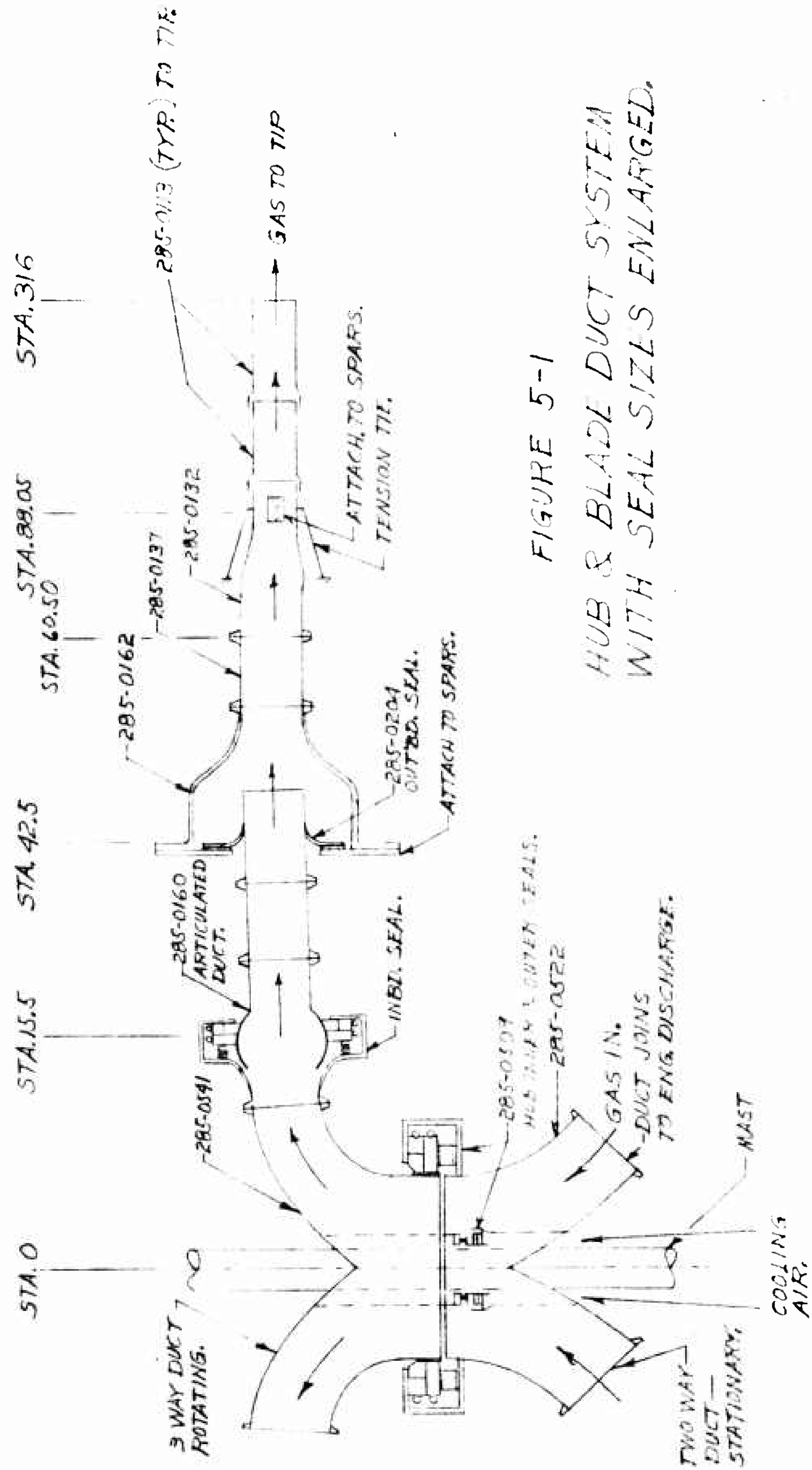


FIGURE 5-1

HUB & BLADE DUCT SYSTEM
WITH SEAL SIZES ENLARGED.

FIGURE 5-2
HUB INNER & OUTER SEALS

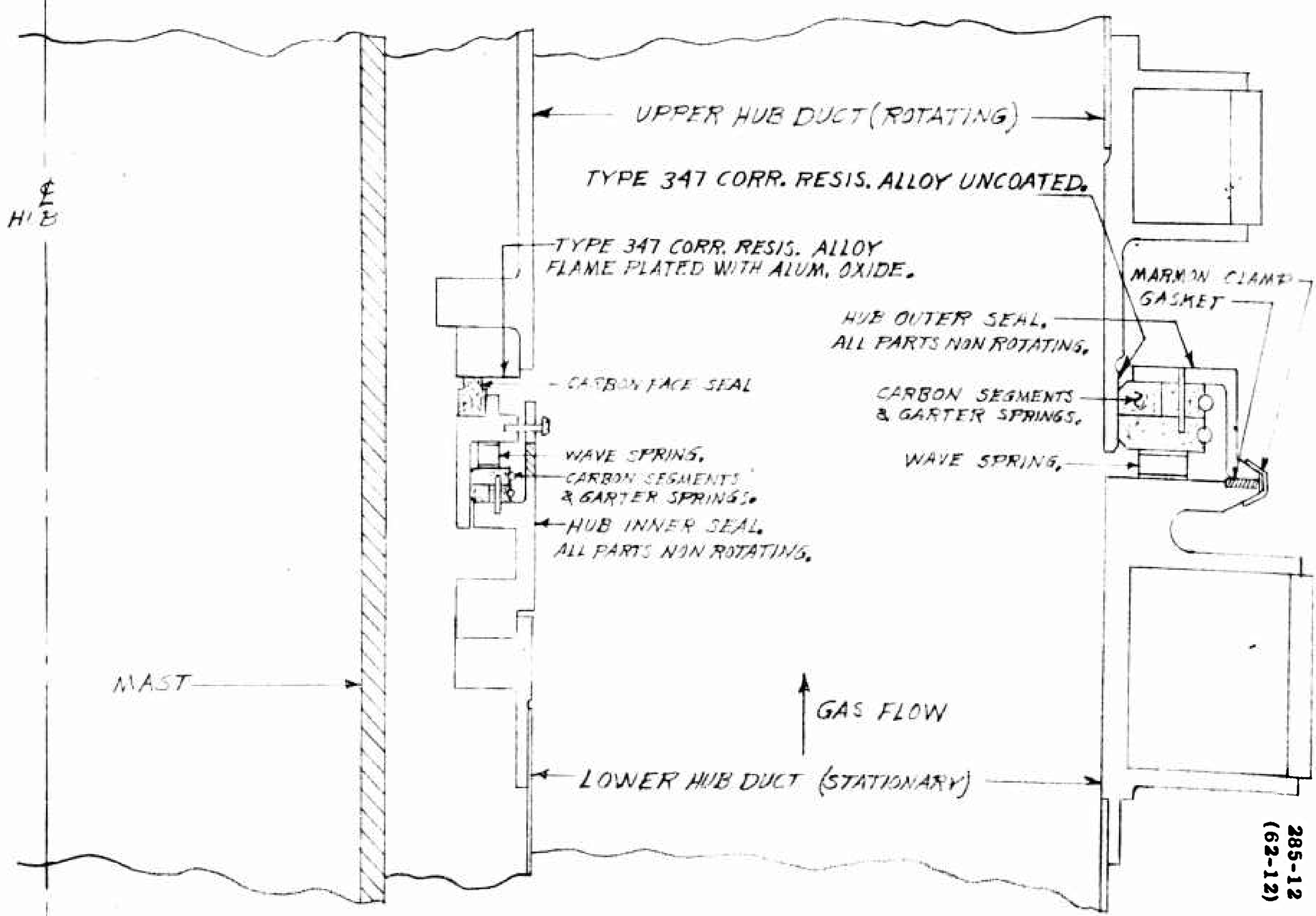
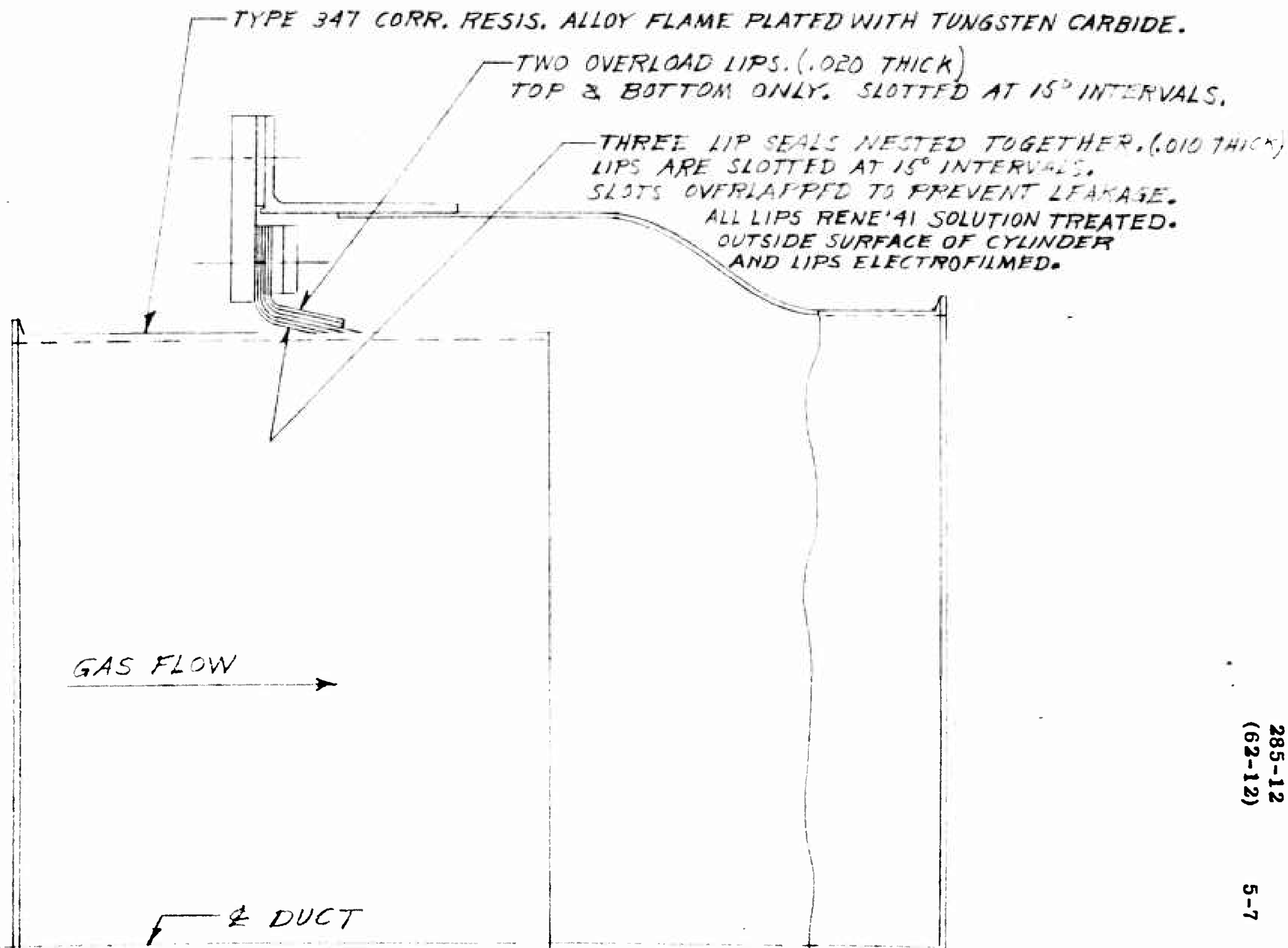


FIGURE 5-3
ARTICULATE DUCT OUTBOARD SEAL



SECTION 6

DESIGN OF CONTROLS

6.1 INTRODUCTION

In designing the controls an attempt was made to make the system as conventional and trouble-free as possible. (See Figures 6-1 and 6-2.) The various components were located so as to keep them small in size and relatively cool. Bearings were given careful attention so that a long life could be anticipated. Corrosion protection, lubrication, and ease of access to all parts were also taken into consideration.

6.2 MATERIAL SELECTION

All control parts were made of either aluminum or steel. Since only one rotor system was built, no castings or forgings, other than hand forged billets, were used. Where space was not a problem the parts were made of aluminum (2024 Aluminum bar and plate and 2014 Aluminum hand forged billets). Where space limited size of parts, they were made of steel (4130 steel bar and plate and 4340 steel hand forged billets).

6.3 DETAIL DESIGN

6.3.1 Control Arrangement

Several control arrangements were drawn and studied. The system using a small swashplate located below the rotor hub was selected since this location makes possible the use of relatively small standard swashplate bearings and keeps the control components away from the hot ducts. This is shown schematically for one blade on Figure 6-1 while the complete assembly drawing is given in Figure 6-2. Geometry of the control system has been laid out so that hub float or blade coning do not appreciably change the blade pitch angle.

6.3.2 Control Bearings

Bearing selection was made on the basis of past performance in the field. In order to avoid multiple bearing installation, self-aligning type roller bearings[1] were used wherever possible. For correlation, actual experimental data were available with this type bearing on other helicopters

1 Manufactured by Shafer Division of Chain Belt Company, Downers Grove, Ill.

of approximately the same size as the Hot Cycle Rotor. Reduced clearance, high quality bearings were specified for all locations.

Bearing forks have been oriented to minimize misalignment. This practice increases bearing life and permits the use of standard $\pm 10^{\circ}$ misaligning bearings in most places. Only at one point in the system was the misaligning angle too large to use a single bearing; a multiple bearing type joint therefore was used. This is bearing point number 12 on Figure 6-1, while the same point is shown at the top of Figure 6-2 in Zone 12. A list of control bearings used in the system is given in Table 6-1.

A lubrication fitting is provided for each bearing With the present configuration none of the bearings operate at over 200°F. For this reason, conventional low-temperature greases are used. Aeroshell-14 (MIL-G-25537), especially developed for helicopter bearings with small oscillations, is used on all but the swashplate bearings. Aeroshell-6 (MIL-L-7711), compounded for rotating helicopter components, is used on the swashplate bearings.

6.3.3 Configuration

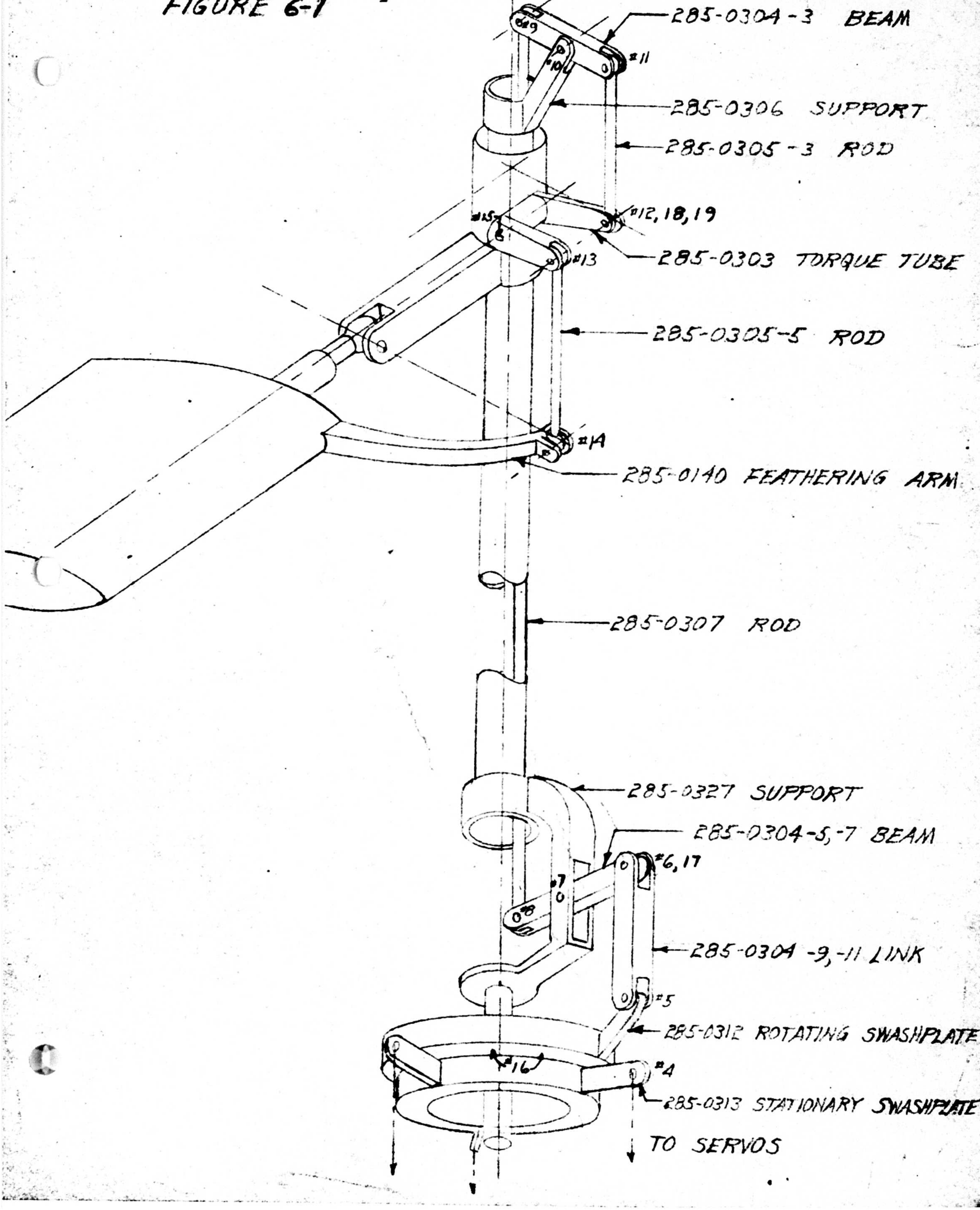
The configuration of the components has been designed to meet actual flight conditions. Since this rotor system was intended primarily as a ground whirl test model, however, fabrication costs were reduced by not machining each component to an optimum design weight. Each control part has been stress checked to meet the ultimate maneuver load and the fatigue load conditions. Most of the parts are designed by the fatigue load conditions. This results in a rugged part, favorable in preventing a buildup of strain in the control system.

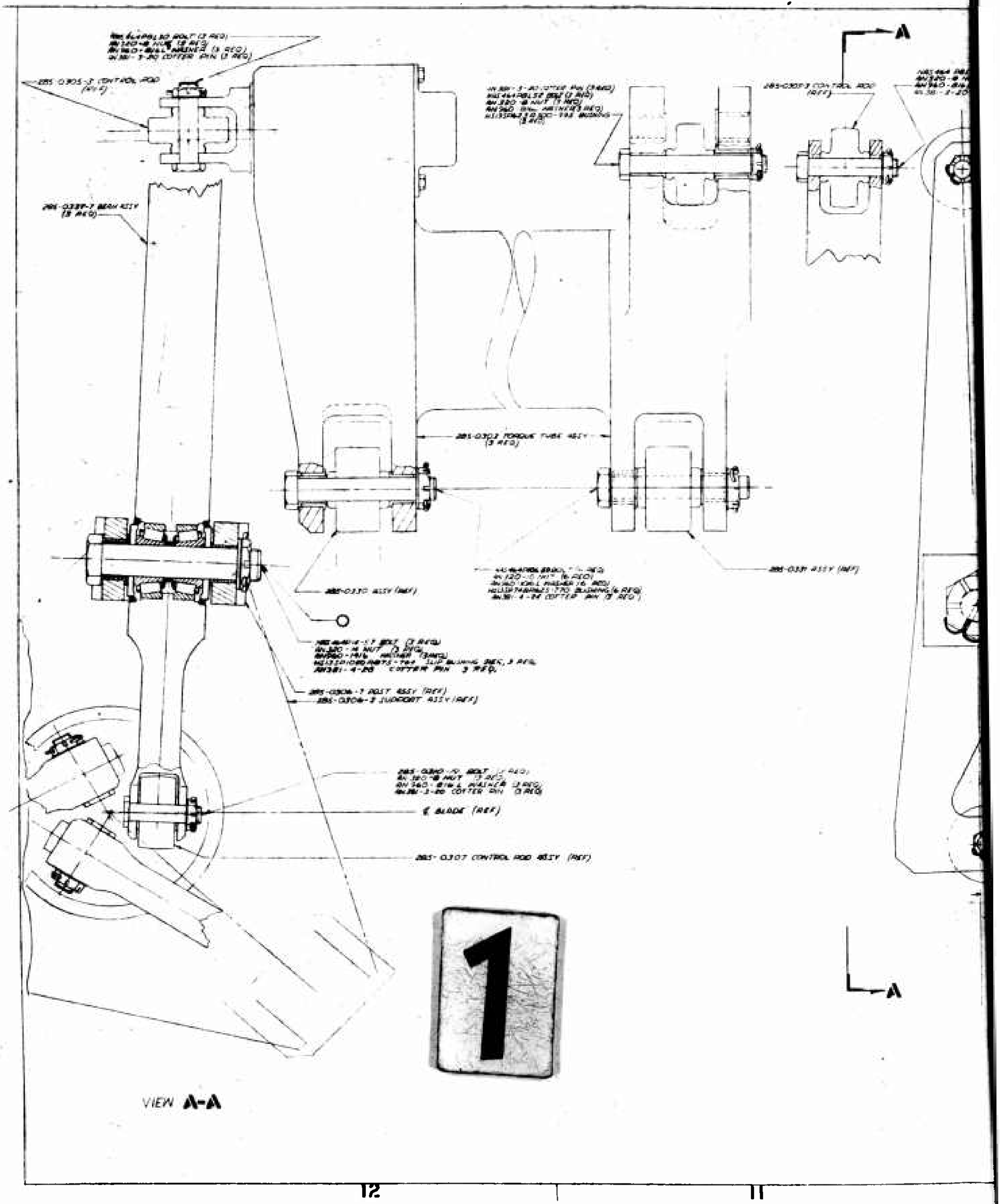
6.4 CONCLUSION

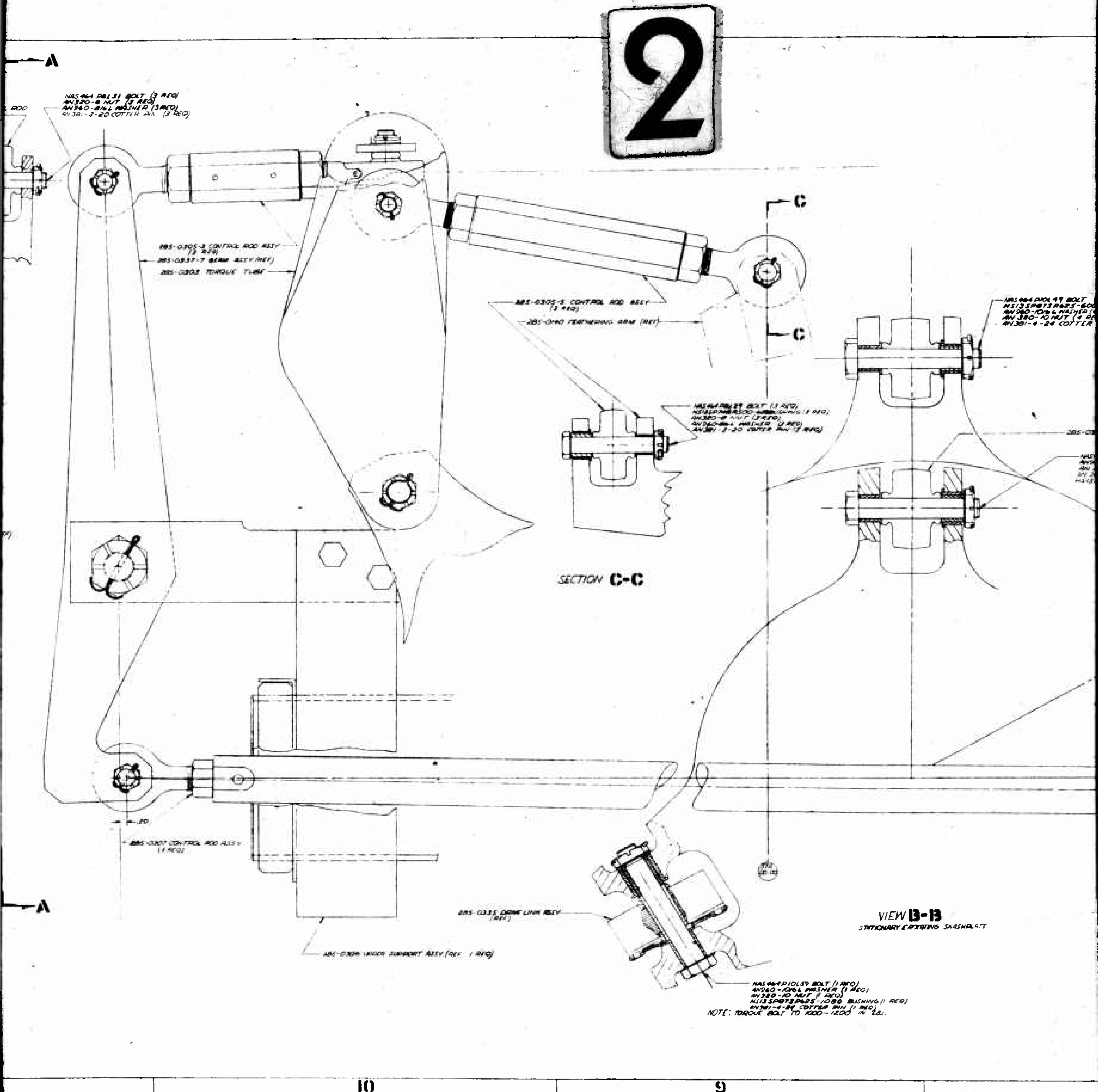
The control system as designed is simple and straight forward. Location of parts has been made to keep them relatively cool and small. Standard materials, bearings and lubricants are used. Assembly or disassembly is easily accomplished. The system components are quite rigid as a result of the use of self aligning bearings and reduced clearances. Finally, the controls are adaptable for use on a flight helicopter.

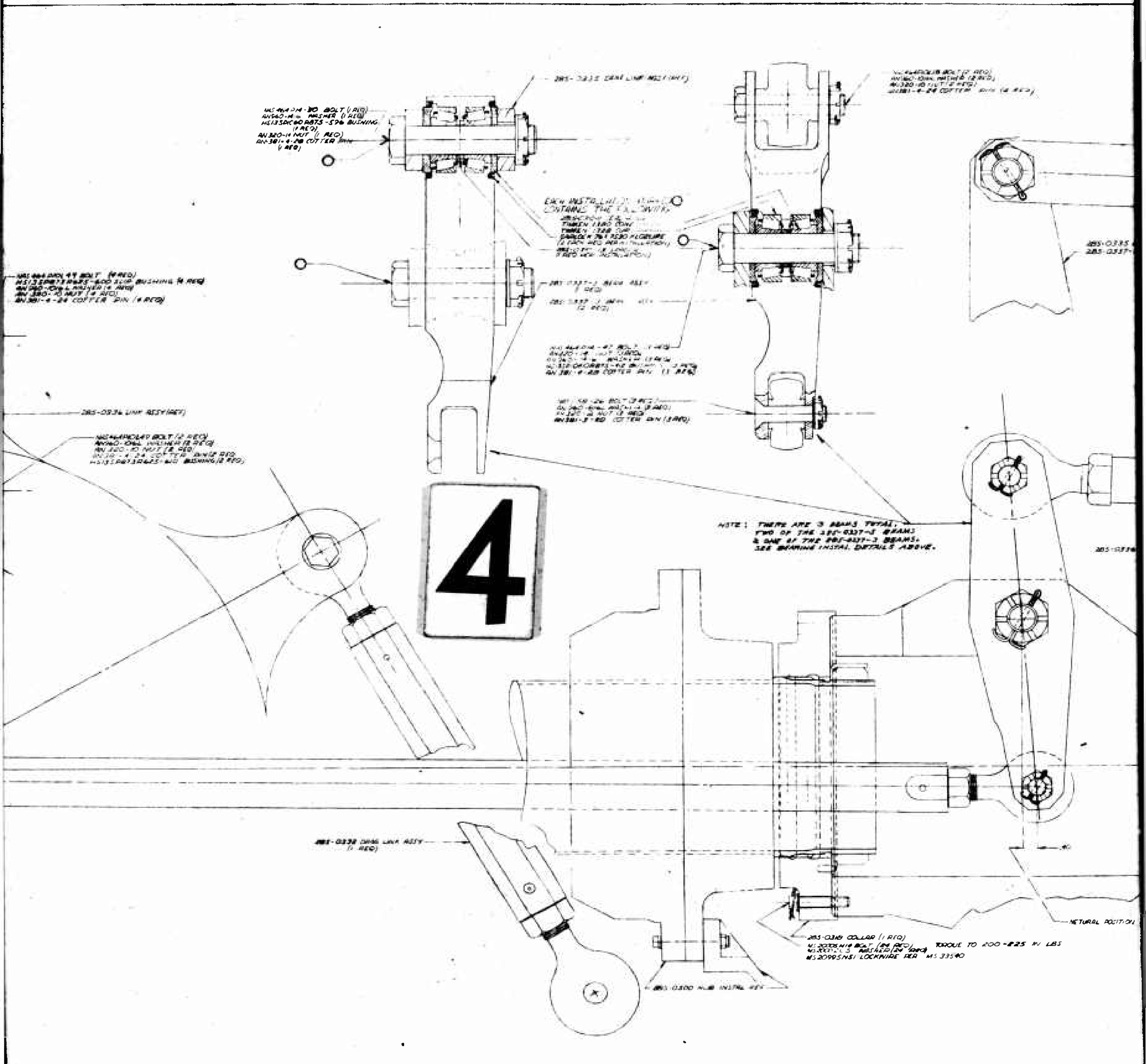
SCHEMATIC OF CONTROL SYSTEM

FIGURE 6-1

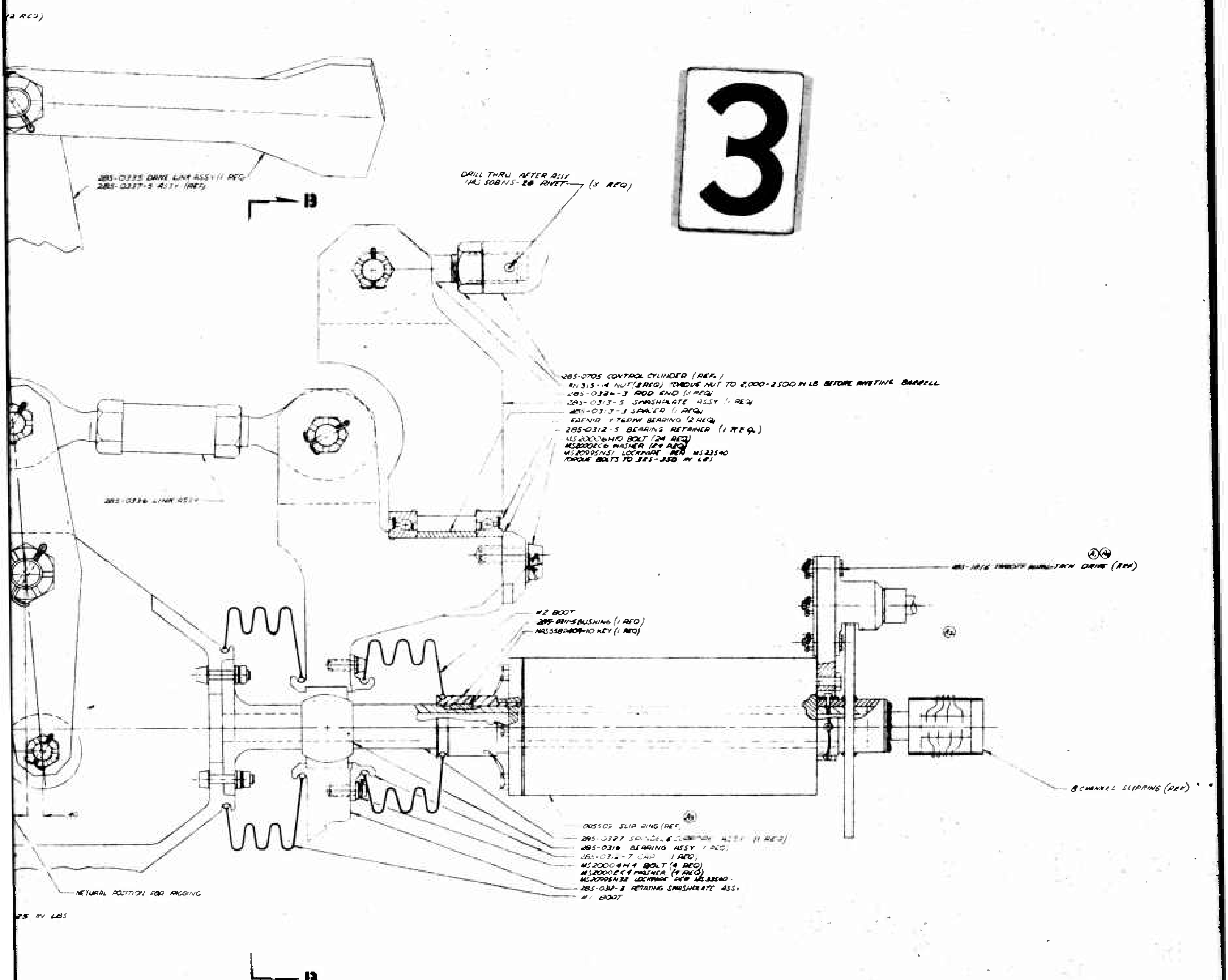



285-0305-3 CONTROL ROD (REF)
285-0303 TORQUE TUBE ASSY (3 REQ)
285-0330 ASSY (REF)
285-0331 ASSY (REF)
285-0306-1 POST ASSY (REF)
285-0306-3 SUPPORT ASSY (REF)
℄ BLADE (REF)
285-0307 CONTROL ROD ASSY (REF)
1
VIEW A-A
12
11


2
A
NAS464 P8L31 BOLT (3 REQ)
AN320-8 NUT (3 REQ)
AN960-816L WASHER (3 REQ)
AN381-3-20 COTTER PIN (3 REQ)
ROD
285-0337-7 BEAM ASSY (REF)
C
285-0305-5 CONTROL ROD ASSY (3 REQ)
SECTION C-C
285-0307 CONTROL ROD ASSY (3 REQ)
A
285-0335 DRIVE LINK ASSY (REF)
VIEW B-B
STATIONARY & ROTATING SWASHPLATE
NAS464 P10L59 BOLT (1 REQ)
AN960-1016L WASHER (1 REQ)
AN320-10 NUT (1 REQ)
AN381-4-24 COTTER PIN (1 REQ)
NOTE: TORQUE BOLT TO 1000-1200 IN LBS.
10
9


MS 464 DM-30 BOLT (1 REQ)
AN960-14 WASHER (1 REQ)
MS13SDIC60 R875-576 BUSHING (1 REQ)
AN 320-14 NUT (1 REQ)
AN 381-4-28 COTTER PIN (1 REQ)
EACH INSTALLATION CONTAINS THE FOLLOWING
NOTE: THERE ARE 3 BEAMS TOTAL, TWO OF THE 285-0337-5 BEAMS & ONE OF THE 285-0337-3 BEAMS. SEE BEARING INSTAL. DETAILS ABOVE.
285-0336 LINK ASSY (REF)
4
285-0332 DRAG LINK ASSY (1 REQ)
285-0300 HUB INSTAL REF
285-0315 COLLAR (1 REQ)
TORQUE TO 200-225 IN LBS
MS20995N51 LOCKWIRE PER MS 33540
NEUTRAL POSITION

8 7 6



3
(2 REQ)
DRILL THRU AFTER ASSY
(MS 20BNS-28 RIVET (3 REQ)
285-0705 CONTROL CYLINDER (REF.)
AN 315-14 NUT(3 REQ) TORQUE NUT TO 2,000-2500 IN LB BEFORE RIVETING BARRELL
285-0326-3 ROD END (1 REQ)
285-0313-5 SWASHPLATE ASSY (1 REQ)
285-0313-3 SPACER (1 REQ)
FAFNIR Y76PW BEARING (2 REQ)
285-0312-5 BEARING RETAINER (1 REQ.)
MS 20006H10 BOLT (24 REQ)
MS20002C6 WASHER (24 REQ)
MS20995N51 LOCKWIRE PER MS33540
TORQUE BOLTS TO 325-350 IN LBS
#2 BOOT
NAS558P404-10 KEY (1 REQ)
TACH DRIVE (REF)
8 CHANNEL SLIPRING (REF)
SLIP RING (REF)
285-0316 BEARING ASSY (1 REQ)
MS20004H4 BOLT (4 REQ)
MS20002C4 WASHER (4 REQ)
ROTATING SWASHPLATE ASSY
#1 BOOT
NETURAL POSITION FOR RIGGING
25 IN LBS
B
B

5 4 3

5

Figure 6-2.

[illegible] 2	1	BOOT	SEE ENGINEERING FOR THIS ITEM	4
[illegible] 1		BOOT		4
			SEE ENGINEERING FOR THIS ITEM	4
				4
[illegible] B	1	RIVET		4
Y176PW1	2	BEARING	MAY BE PURCHASED FROM [illegible] BEARING CO LA	4
MS20995VS		LOCKWIRE		4
MS20995N32		LOCKWIRE		3
MS20002C4	2	WASHER		3
				3
				3
MS[illegible]	1	KEY		4
[illegible]7532	14	KLOZURE	THE GARLOCK PACKING CO 2303 E [illegible] ST LA 21, CAL	7
[illegible]28	14	CUP	TIMKEN ROLLER BEARING CO [illegible] S. FLOWER ST.	7
[illegible]80	14	CONE	LOS ANGELES 7, CALIFORNIA	7
MS20002C5	24	WASHER		6
MS20005H4	24	BOLT		4
AN380-4-[illegible]	7	COTTER PIN		
AN380-4-4	12			
AN380-3-2	18	COTTER PIN		
AN320-14	7	NUT		
AN320-[illegible]	13			
AN320-8	18			
AN315-14	3	NUT		
[illegible]		WASHER		
[illegible]				
[illegible]				
[illegible]		WASHER		
[illegible]		BUSHING		8
[illegible]		BUSHING		8
[illegible]		BUSHING		9
[illegible]		BUSHING		8
[illegible]	1	BUSHING		7
[illegible]	1	BUSHING		7
[illegible]	6	BUSHING		12
[illegible]	2	BUSHING		12
[illegible]	3	BOLT		7
MS20006H10	24	BOLT		4
NAS464PH 57	3	BOLT		12
NAS464-H-50	1			8
NAS464PH-47	3			7
NAS464P10-57	1			7
NAS464P10-50	6			12
NAS464P[illegible]47	6			8
NAS464P[illegible]	2			6
NAS464-[illegible]	3			12
NAS464-[illegible]	3			9
NAS464-[illegible]	6	BOLT		11
MS20006H4	4	BOLT		4
285-0314-5	1	BUSHING		4
285-0310-9	3	BOLT		12
285-0336	2	LINK ASSY		5
285-0337-7	4	BEAM ASSY		12
285-0337-5	1	BEAM ASSY		7
285-0337-3	4	BEAM ASSY		7
285-0335	1	DRIVE LINK ASSY		5

285-0300

A

285-0332		DRIVE LINK ASSY	8
285-0327	1	[illegible] ASSY	4
285-[illegible]-3	3	ROD END	4
285-0318		COLLAR	6
285-[illegible]		BEARING ASSY	4
285-[illegible]-5		[illegible] ASSY	4
285-0313-3	1	[illegible]	4
285-[illegible]		CAP	4
285-[illegible]-5	1	[illegible]	4
285-[illegible]	1	[illegible]	4
285-[illegible]-3	1	SPACER	7
285-0310	4	[illegible]	7
285-0307	3	CONTROL ROD ASSY	10
285-[illegible]		[illegible] SUPPORT ASSY	
285-0305-5	3	CONTROL ROD ASSY	9
285-[illegible]-3	3	CONTROL ROD ASSY	10
285-0303	3	[illegible] TUBE ASSY	10

[illegible] DRIVE (REF)

8 CHANNEL SLIPRING (REF)

NOTES UNLESS OTHERWISE SPECIFIED:
1 CONTROLS ARE SHOWN IN THE NEUTRAL POSITION. ZERO STRAP TWIST
2 GARLOCK KLOZURES ARE TO BE FURNISHED WITH CAD PLATED STL CASES
3 BOLT TORQUES PER HP 6-2 UNLESS OTHERWISE NOTED.

285 | 285-0300

CONTROLS INSTAL-HOT CYCLE
ROTOR UPPER FLIGHT

285-0300

3 2 1

TABLE 6-1

CONTROL BEARINGS USED

Bearing No. (See Figure 6-1)	Bearing Used
4	Shafer B-49194
5	Shafer B-4914
6	Shafer B-4914
7	Cone 1380 Timken Cup 1328
8	Shafer B-49195
9	Shafer B-49195
10	Cone 1380 Timken Cup 1328
11	Shafer A-49196
12	Shafer A-49196
13	Shafer A-49196
14	Shafer A-49196
15	Shafer A-49200
16	(Swashplate Bearing) Fafnir and 176 PW 1
17	Cone 1380 Timken Cup 1328
18	Cone 13685 Timken Cup 13620
19	Cone 1380 Timken Cup 1328

SECTION 7

REFERENCES

3-1 Boswell, C. C.; "Rotor System Preliminary Design, Hot Cycle Rotor System," HTC-AD Report No. 285-7, 30 September 1956.

3-2 Stanley, Jr., H. C.; "Results of Component Test Program, Hot Cycle Rotor System," Test No. 5 - Blade Screening Fatigue Test, HTC-AD Report No. 285-9-5, 1 May 1959.

3-3 Smith, C. R.; "Structural Analysis, Item 4b, Hot Cycle Rotor System," HTC-AD Report No. 285-13 (62-13), March 1962.

3-4 French, J. C.; "Materials and Processes, Hot Cycle Rotor System," HTC-AD Report No. 285-18 (62-18), March 1962.

7-1 La Forge, S.; Shyffer, B.; Rittamel, F.; "Aerodynamics and Heat Transfer, Hot Cycle Rotor System," HTC-AD Report No. 285-4, 29 February 1956.

APPENDIX 1

DESIGN CRITERIA

APPENDIX 1.

DESIGN CRITERIA

TABLE OF CONTENTS

1.1 INTRODUCTION

This section presents the structural design criteria for the Hot Cycle Rotor. The rotor is a three-bladed configuration with coning blades and floating hub. Design parameters of the rotor system are based on a vehicle gross weight of 15,300 pounds. Power is provided by two GE T-64 engines.

Maximum design maneuver load factor is 2.5g limit with an ultimate safety factor of 1.5. Maximum design loads are to be considered in combination with maximum temperature and pressure.

The design objective for service life is 1000 hours. Inasmuch as it is virtually impossible to predict an accurate vibratory load spectrum, design for fatigue is based on a weighted fatigue condition. The cyclic load level for this condition is estimated at 75% of the approach-to-land condition. All structural components are designed for infinite life at the stress levels imposed by the Weighted Fatigue condition.

1.2 GENERAL PARAMETERS

A. Design Gross Weight	15,300 lb.
B. Type Rotor System	Floating hub, coning blade
C. Duct Area in each Blade	54.8 sq. in.
D. Blade Utilization	45.3%
E. Cruise Speed	100 knots
F. Blade Tip Speed	
1. Hovering, cruise and maneuver	700 fps
2. Over-rev (normal x 1.25)	875 fps at blade pitch = 0^{o} at 3/4 radius
G. Engine	GE T-64 (two)

H. Engine Discharge

	Temp. R	Temp. F	Pres. Ratio	Pres. (psig)	Gas Mass Flow lb/sec
1. Current Engine					
a. Cruise at S. L. Std (Normal Rated Power)	1499	1039	2.61	23.6	23.8
b. Take-off at S. L. Std (Military Rated Power)	1577	1117	2.83	26.9	25.0
2. Advanced Engine					
a. Cruise at S. L. Std (Normal Rated Power)	1577	1117	2.83	26.9	25.0
b. Take-off at S. L. Std (Military Rated Power)	1644	1184	2.97	29.0	26 0

1.3 BLADE CONFIGURATION

A. Number of Blades	3
B. Airfoil	NACA 0018
C. Chord	31.5 inches
D. Radius	27.5 ft (330 in.) to center of tip nozzle
E. Twist	8° washout (in 330 inches)
F. Feathering Point	26.2% chord (8.25 in. from LE)
G. Pitch Setting (Built In)	At the 3/4 radius, pitch = $+7.6^{\circ}$ in relation to plane of rotation
H. Deformation of Contour Permitted	Limited to total (both sides) of 1% (.315 in.) of chord. If practical, there should be no reverse curvature when airfoil is deformed by temperature or load.
I. Balance Desired	Incremental balance at or ahead of 25% chord point (7.875 from LE) from Sta 100 to tip.
J. Natural Frequency Required	
1. Normal	$N_{r_1} > 2.2 < 2.8$/Rev
	$N_{r_2} > 4.2 < 4.8$/Rev
2. Chordwise	$N_{r_1} > 1.3 < 1.7$/Rev

Through range of tip speeds from 665 to 735 fps.

1.4 LOADS AND LOAD FACTORS

A. Load Factor in Maneuver	2.5g limit at design gross weight (per MIL-S-8698 (ASG) Paragraph 3.1.10)
B. Load Factor in Ground Flapping	
1. Blade Droop Stop & Hub 10° Tilt Stop	2.5g limit
2. Hub 2° Tilt Stop	2g limit
C. Wind Loads	Shall be those resulting from a 40-knot wind from any horizontal direction (per MIL-S-8698) (ASG) Paragraph 3.4.6.2)
D. Rotor Starting Condition	Static thrust (max.) of 500 lb/blade at blade tips reacted by rotational inertia of rotor. Blades in -2°, 1g dropped position. Rotational speed is zero.
E. External Chordwise Pressure Distribution, Cruise and 2.5g Maneuver Condition	Use data in HTC-AD Report No. 285-7, "Hot Cycle Rotor System, Item 3", pp. 45-46, Figs. 25, 26 & 27, and increase values by ratio of tip speed squared $\left(\frac{700^2}{650^2} = 1.16\right)$ and add 2.1 psi from 55% to 85% chord. (Inertia loads are included.) In addition, buffeting fatigue of blade aft skins must be guarded against by comparing gages and panel sizes with those of existing high speed aircraft.

F. Blade Torsion Loads

1. Cruise Condition
(coning = 4°, tilt = 0° to 3° aft) 6,550 $\pm$ 13,860 ip limit

2. Weighted Fatigue Condition
(coning = 4°, tilt = 0° to 6° aft) 13,100 $\pm$ 25,140 ip limit

3. Maneuver, 2-1/2g recovery
(coning = 10°, tilt = 10 aft) 20,170 $\pm$ 32,300 ip limit

Note:

a. Positive value indicates blade nose down.

b. Values given include strap torsion.

c. Steady torsion should be checked in both directions.

d. To be conservative, when analyzing swashplate and lower controls, critical phasing of above loads from each of the three blades should be used.

e. In lieu of a more accurate dynamic analysis, an arbitrary dynamic (limit) factor of 1.25 shall be used for the ultimate conditions of blade root torsion (Item F. 3 above). This factor may be reduced to 1.10 between actuating cylinders and the top of the mast. The usual 1.5 ultimate factor is also required.

f. The hydraulic cylinder load input shall be capable of supplying sufficient load to actuate the rotor blades under the design maneuvers (Item F. 1 and F. 3 above).

g. The hydraulic servo system shall be restricted to provide a rate of swashplate travel of 20 deg in no less than 0.50 nor more than 0.75 sec.

h. For whirl tower test only, the control loads may be reduced as follows:

(1) Steady component - same as corresponding flight values.

(2) Cyclic component - 40% of corresponding flight values.

G. Blade Shear Loads

1. Normal Shear

See curves of Section 4.

2. Chordwise Shear just Outboard of Blade Strap Fittings

(a) Cruise Condition	100 ± 260 lb. limit
(b) Weighted Fatigue Condition	200 ± 385 lb. limit
(c) 2-1/2g Maneuver Condition	100 ± 1550 lb. limit

Note: (1) Positive loads are up and aft on hub.

(2) Normal shears do not include control forces.

(3) Chordwise shears do include dissymmetry of converging straps.

H. Blade Bending Moments

1. Chordwise

Cruise at 100 knots	± 41, 050 ip limit
Weighted fatigue	± 82, 100 ip limit
2-1/2g Maneuver	± 253, 000 ip limit
Over-Rev	No significant bending stresses

Note: Chordwise moments are given in a plane described by the blade feathering and flapping axes, with blade coned.

2. Normal Bending Moments

See Curves of Section 4.

I. Duct Operating Pressure and Temperature

1. 910 hours of life:

a. Desired	1117°F	26.9 psig
b. Minimum	1039°F	23.6 psig

2. 90 hours of life:

a. Desired	1184°F	29.0 psig
b. Minimum	1117°F	26.9 psig

3. Power off, rotor rotating:	800°F	-4.0 psig

Note: 1. The figures shown as desired must be used for design except in those cases where a severe cost or time penalty results. In such a case, the minimum figures may be used provided a later simple change (such as material substitution) will permit operation at the higher values.

J. Hub In-Plane Loads

1. Weighted Fatigue Condition

Use a 1.0g thrust with the vector at 6° to the shaft and with the hub inclined 5° to the shaft, or same lateral component with 1.5g thrust.

2. 2.5g Maneuver (ultimate condition)

Use a 2.5g thrust with the vector at 10° to the shaft and with the hub inclined 8° to the shaft.

K. FAA Factors — 1.15 fitting factor, 1.25 casting factor, etc., need <u>not</u> be applied.

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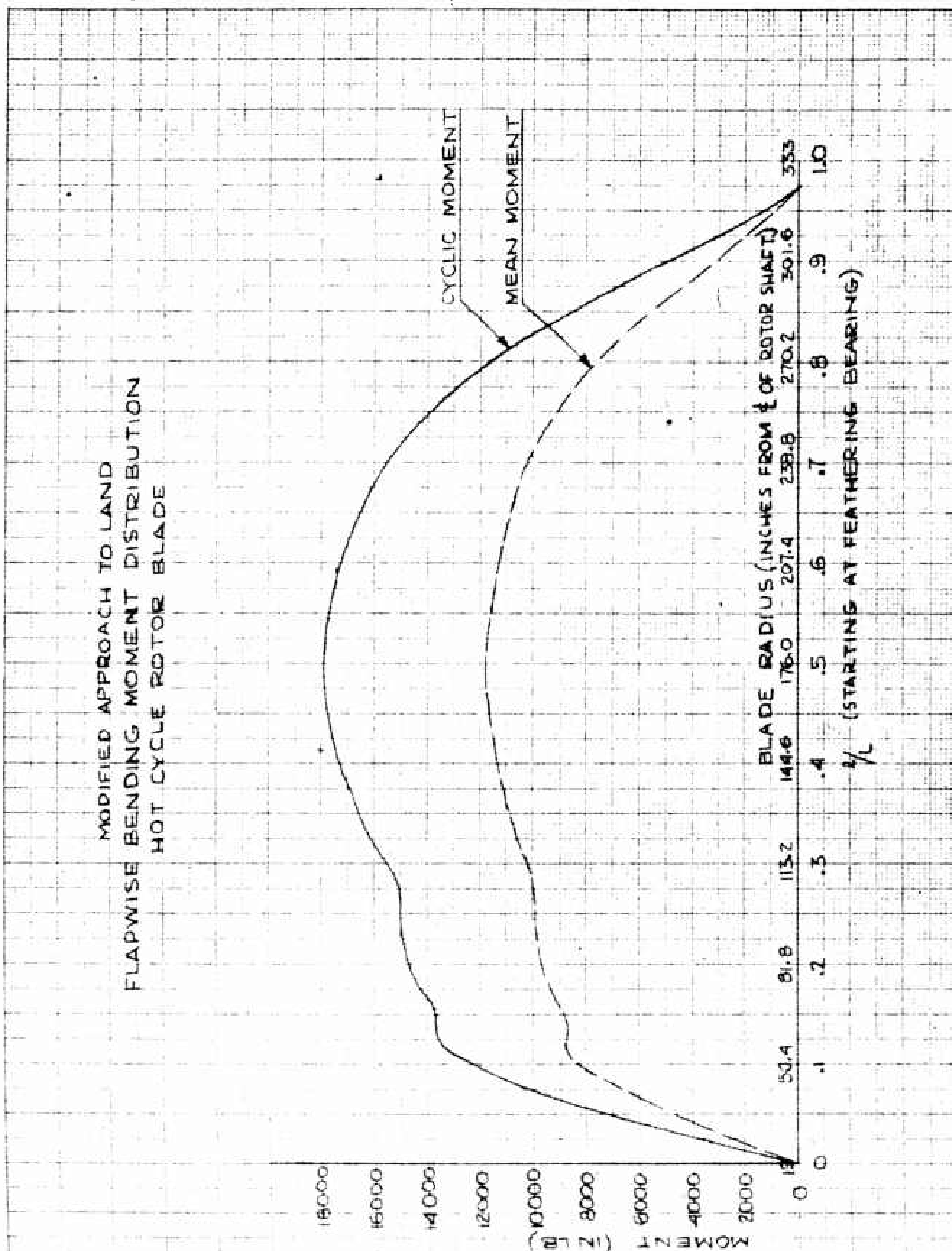

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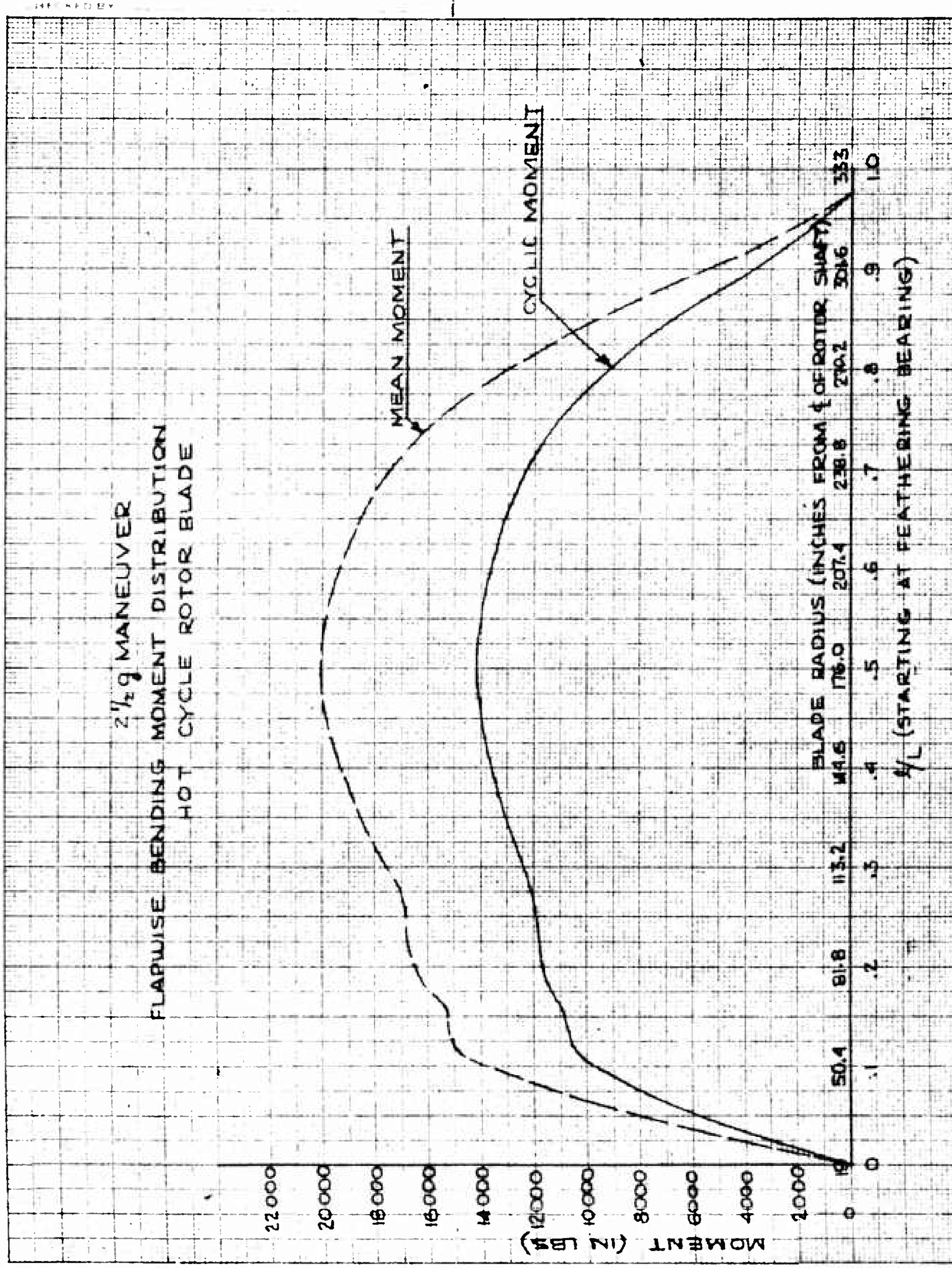

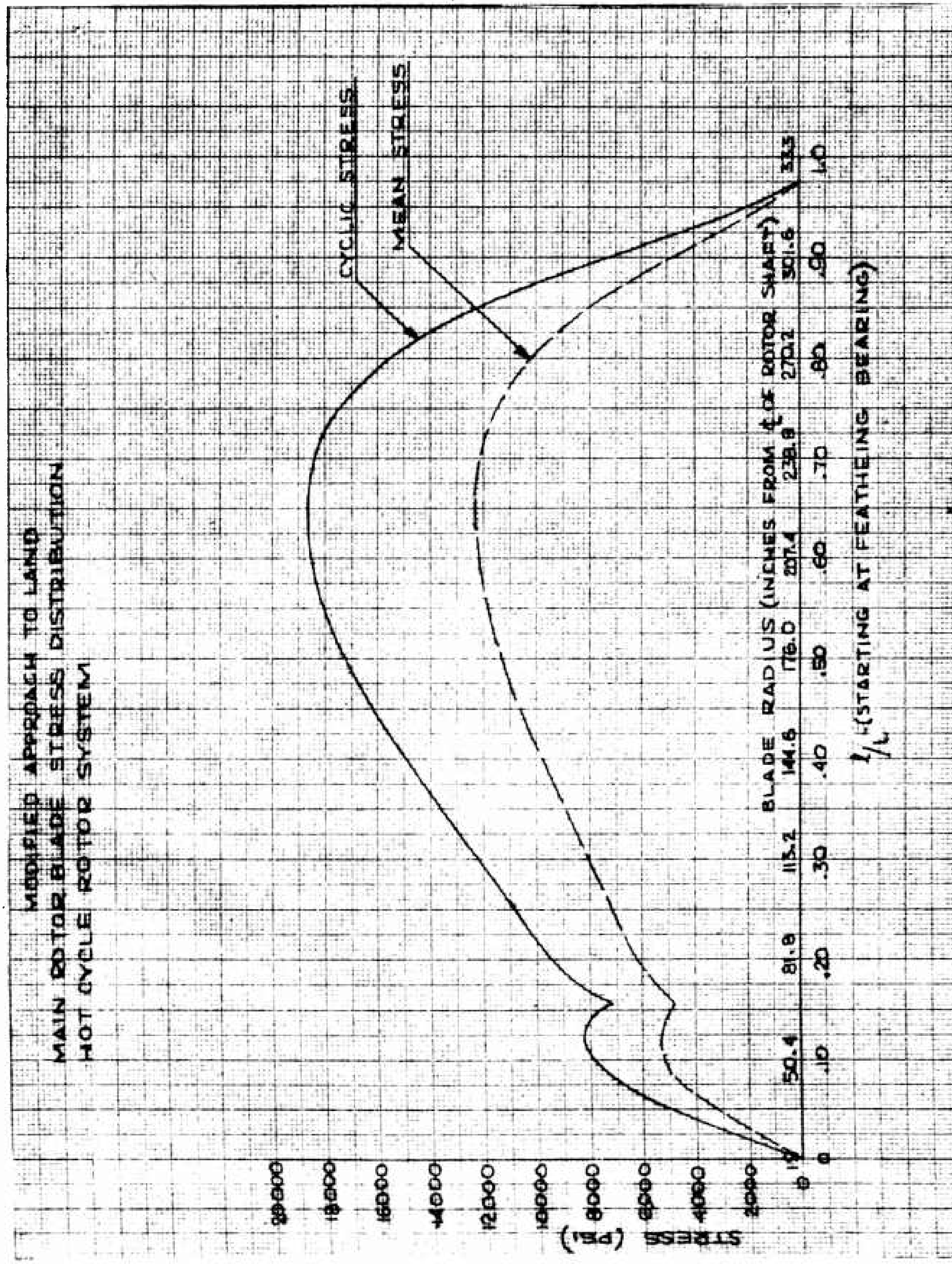
MODIFIED APPROACH TO LAND
MAIN ROTOR BLADE STRESS DISTRIBUTION
HOT CYCLE ROTOR SYSTEM
CYCLIC STRESS
MEAN STRESS
BLADE RADIUS (INCHES FROM ℄ OF ROTOR SHAFT)
50.4 81.8 113.2 144.6 176.0 207.4 238.8 270.2 301.6 333
r/R (STARTING AT FEATHERING BEARING)
0 .10 .20 .30 .40 .50 .60 .70 .80 .90 1.0
STRESS (PSI)
0 2000 4000 6000 8000 10000 12000 14000 16000 18000 20000

ANALYSIS
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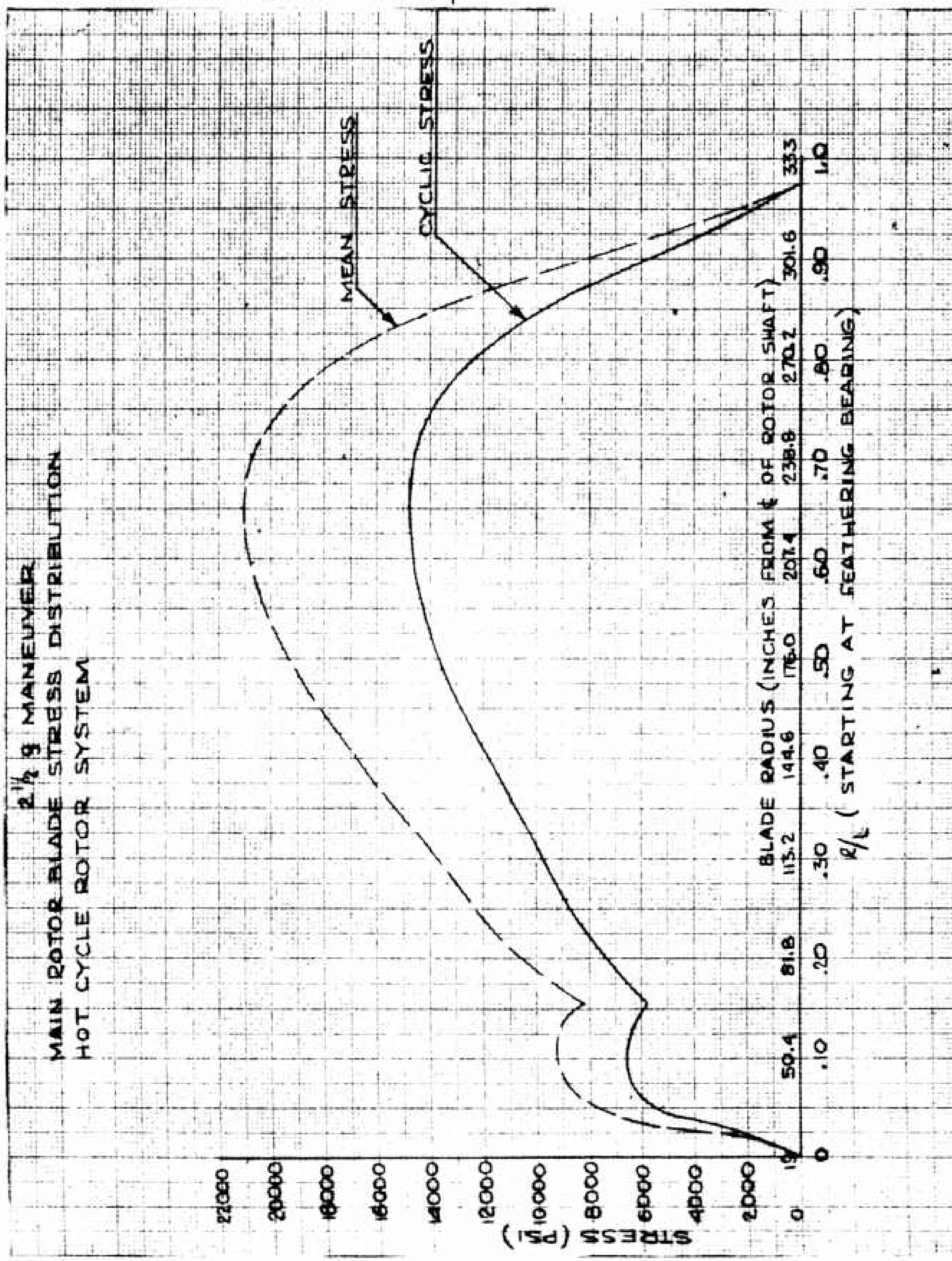

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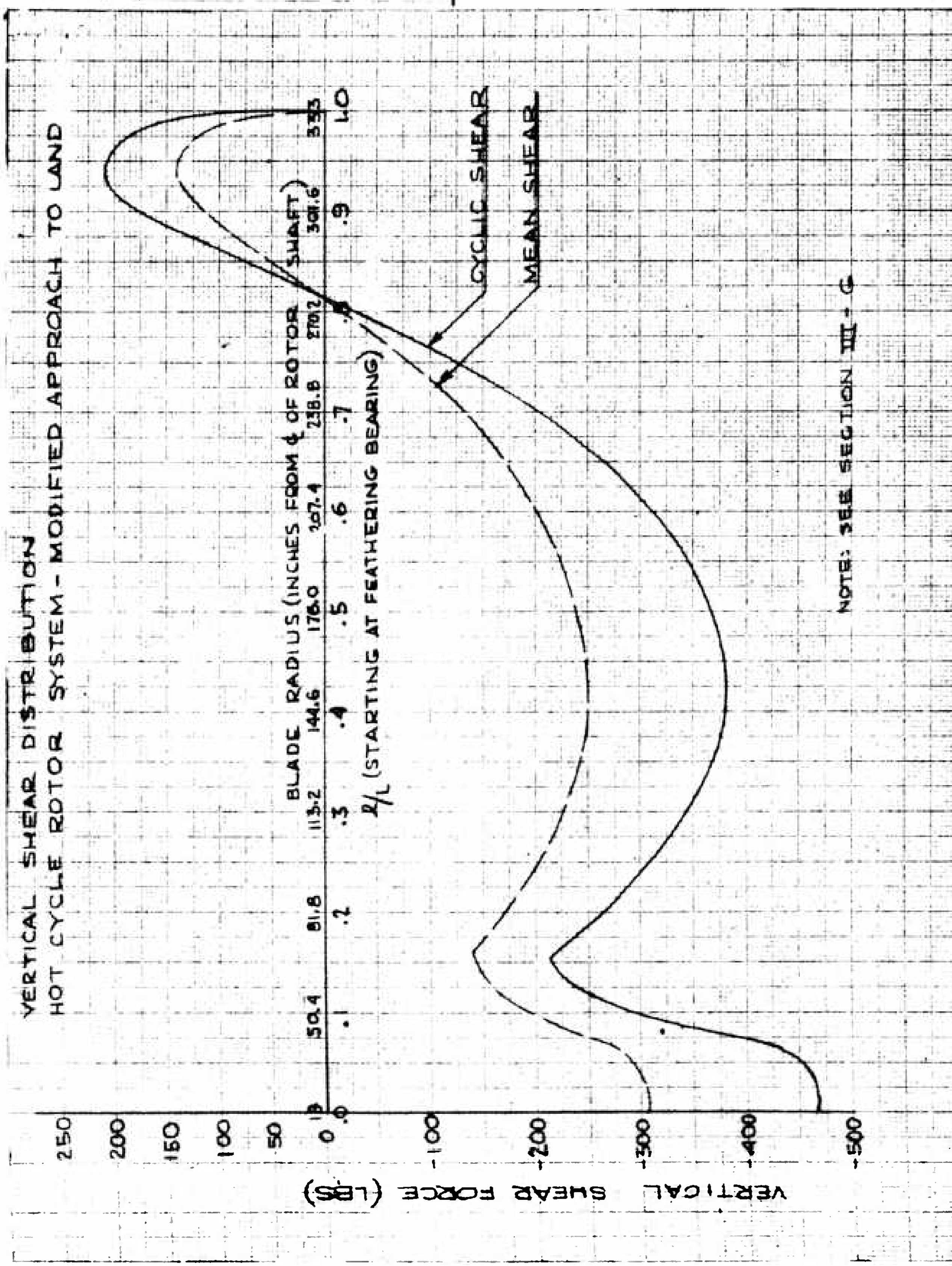

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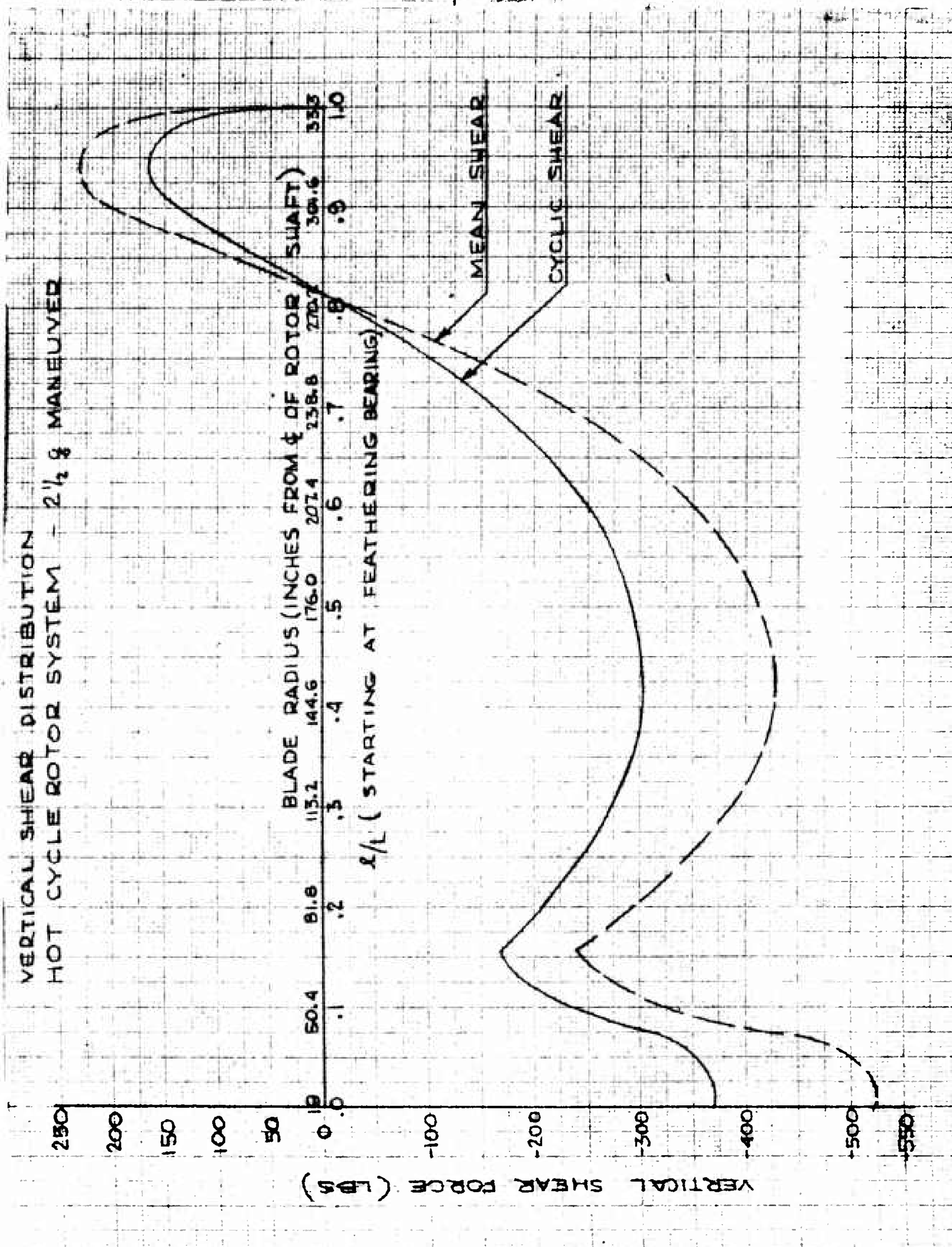
MODEL 285 REPORT NO. **(62-12)** PAGE **1.4.10**



1.5 RELATIVE MOVEMENTS; BLADE, HUB AND CONTROLS

Note: (1) Cyclic Pitch is defined as $\Theta_{1_s} \sin\psi + \Theta_{2_s} \cos\psi$, where ψ = blade azimuth location measured from the blade aft position, and Θ_{1_s} and Θ_{2_s} are measured with respect to the neutral swashplate position.

(2) Under dynamic transient conditions, hub lag relative to the swashplate may be as much as 2.88° <u>beyond</u> the <u>steady state tilt.</u> It will be restricted to this value by hydraulic flow restriction. (See note g, page 1.4.2.

A. Hub Tilt and Blade Coning, Flapping and Feathering Angles.

1. Clearance Cond.

Hub Tilt - relative to mast:

a. at normal r.p.m.	10° in all azimuth positions
b. at zero r.p.m.	2° in all azimuth positions
Blade Coning - relative to hub	15° up, 2° down
Blade Collective Pitch at 3/4 Radius	0° to 12°
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = \pm 10^\circ$, $\Theta_{2_s} = \pm 7^\circ$

2. Level Flight, 100 knot Cruise

Hub Tilt - relative to mast	0° to 3° aft
Blade Coning - relative to hub	4.0°
Blade Flapping - relative to hub	$\pm$0.25° at 2/rev

Blade Collective Pitch at 3/4 Radius	$+7.6^{\circ}$
Blade Cyclic Pitch - relative to hub	$\Theta_1 = 0^{\circ}$ to -3.8°, $\Theta_2 = 1.7^{\circ}$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = 0^{\circ}$ to -0.8°, $\Theta_{2_s} = 1.7^{\circ}$

3. 2.5g Maneuver Condition at 100 knots. (This condition is a dynamic maneuver; therefore, its description is presented in three parts.)

(a) Cyclic Stick Pull-Back

Helicopter Load Factor	1.0g
Hub Tilt - relative to mast	10° aft
Blade Coning - relative to hub	$+4.0^{\circ}$
Blade Flapping - relative to hub	$\pm 0.25^{\circ}$ at 2/rev
Blade Collective Pitch at 3/4 Radius	$+7.6^{\circ}$
Blade Cyclic Pitch - relative to hub	$\Theta_1 = -3.8^{\circ}$, $\Theta_2 = +1.7^{\circ}$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = +0.2^{\circ}$, $\Theta_{2_s} = +1.7^{\circ}$

(b) Application of Full Collective Pitch and Decrease in Feathering Angle

Helicopter Load Factor	2.5g
Hub Tilt - relative to mast	10° aft
Blade Coning - relative to hub	$+10^{\circ}$

Blade Flapping - relative to hub	$\pm 0.6^{\circ}$ at 2/rev
Collective Pitch at 3/4 R	12°
Blade Cyclic Pitch - relative to hub	$\Theta_1 = -9.5^{\circ}$, $\Theta_2 = +4.25^{\circ}$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = +0.5^{\circ}$, $\Theta_{2_s} = +4.25^{\circ}$

(c) Recovery (Cyclic pitch stick moved an additional 2.88°* forward)

Helicopter Load Factor	2.5g
Hub Tilt - relative to mast	10° aft*
Blade Coning - relative to hub	$+10^{\circ}$
Blade Flapping - relative to hub	$\pm 0.6^{\circ}$ at 2/rev
Blade Collective Pitch at 3/4 Radius	$+12^{\circ}$
Blade Cyclic Pitch - relative to hub	$\Theta_1 = -12.38^{\circ}$*, $\Theta_2 = +4.25^{\circ}$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = -2.38^{\circ}$*, $\Theta_{2_s} = +4.25^{\circ}$

* See Note (2) page 1.5.1

4. Weighted Fatigue Condition

Hub Tilt - relative to mast	0° to 6° aft
Blade Coning - relative to hub	$+4^\circ$ to $+8.0^\circ$, whichever is critical
Blade Flapping - relative to hub	$\pm 0.5^\circ$ at 2/rev
Blade Collective Pitch - at 3/4 Radius	$+7.6^\circ$
Blade Cyclic Pitch - relative to hub	$\Theta_1 = 7.6^\circ$, $\Theta_2 = +3.4^\circ$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = 1.6^\circ$, $\Theta_{2_s} = +3.4^\circ$

5. Entry into Autorotation from Cruise

Hub Tilt - relative to mast	3° aft
Blade Coning - relative to hub	$+4^\circ$
Blade Flapping - relative to hub	$\pm 0.25^\circ$ at 2/rev
Blade Collective Pitch at 3/4 Radius	0°
Blade Cyclic Pitch - relative to hub	$\Theta_1 = 6.68^\circ$, $\Theta_2 = +1.7^\circ$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = 3.68^\circ$, $\Theta_{2_s} = +1.7^\circ$

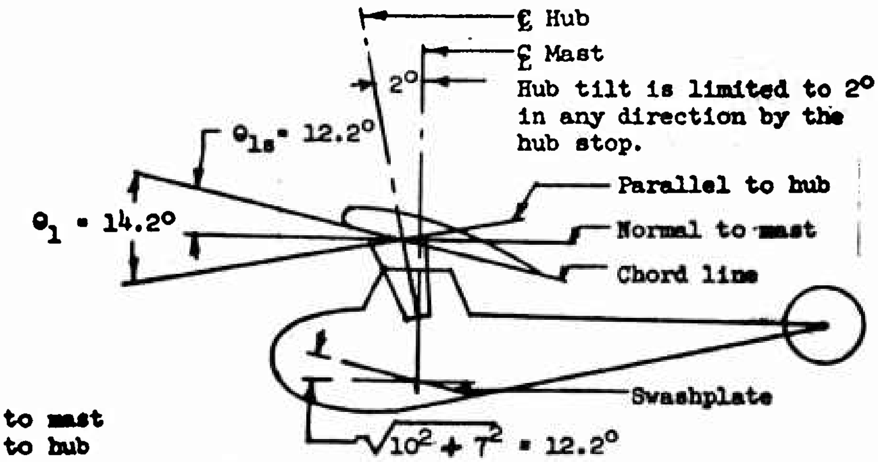
6. 2.5g Autorotation Maneuver at 100 knots (flareout)

Helicopter Load Factor	2.5g
Hub Tilt - relative to mast	10° aft
Blade Coning - relative to hub	$+10^\circ$
Blade Flapping - relative to hub	$\pm 0.6^\circ$ at 2/rev
Blade Collective Pitch at 3/4 Radius	$+3^\circ$
Blade Cyclic Pitch - relative to hub	$\Theta_1 = -11.5^\circ$, $\Theta_2 = 0^\circ$
Blade Cyclic Pitch - relative to mast	$\Theta_{1_s} = -1.5^\circ$, $\Theta_{2_s} = 0^\circ$

STRAP WINDUP

HUB AND ROTOR BLADE GROUND CLEARANCE CHECK

VIEW SHOWS AN ADVANCING BLADE AT APPROXIMATELY 135° AZIMUTH

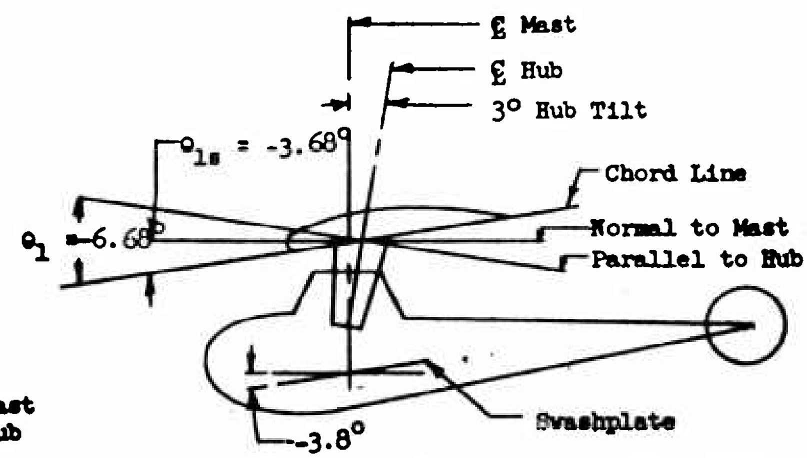


Θ_{1s} = Pitch relative to mast
Θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAX. STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
12°-7.6°=4.4° at pitch arm	+14.2° + 4.4° =+18.6° (Blade Nose Up)	-14.2° + 4.4° =-9.8° (Blade Nose Down)
0°-7.6°=-7.6° at pitch arm	+14.2° - 7.6° =+6.6° (Blade Nose Up)	-14.2° — 7.6° =-21.8° (Blade Nose Down)

ENTRY INTO AN AUTOROTATION MANEUVER FROM A CRUISE CONDITION

VIEW SHOWS AN ADVANCING BLADE AT 90° AZIMUTH



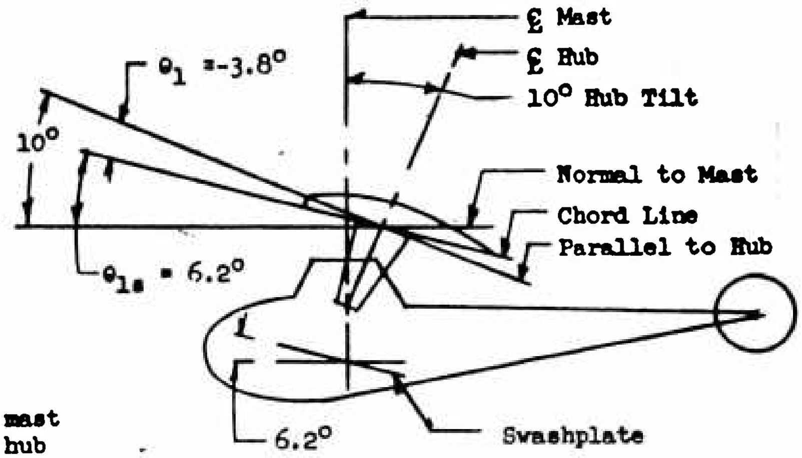
Θ_{1s} = Pitch relative to mast
Θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAX. STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
0°-7.6°= -7.6° at pitch arm	-6.68 - 7.6° = -14.28° (Blade Nose Down)	+6.68°-7.6° = -0.92° (Blade Nose Down)

STRAP WINDUP

2.5G MANEUVER CONDITION AT 100 KNOTS
STEP I - CYCLIC STICK PULL BACK

VIEW SHOWS AN
ADVANCING BLADE
AT 90° AZIMUTH

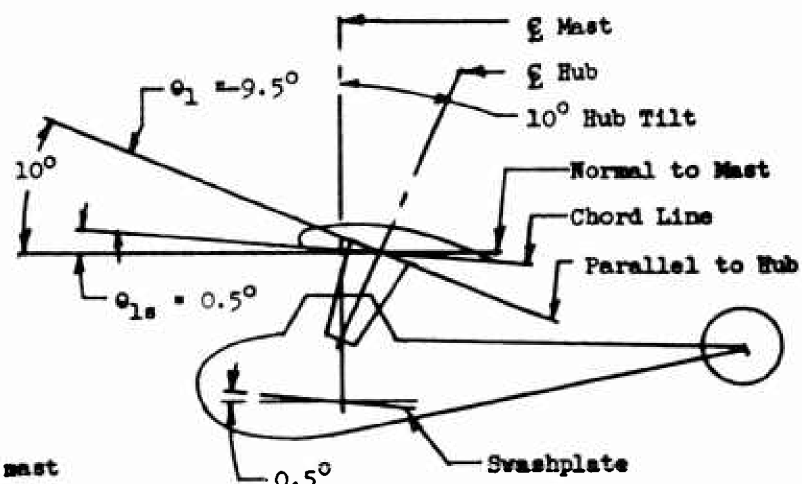


θ_{1s} = Pitch relative to mast
θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAXIMUM STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
7.6°-7.6°=0° at Pitch Arm	-3.8° (Blade Nose Down)	+3.8° (Blade Nose Up)

2.5G MANEUVER CONDITION AT 100 KNOTS
STEP 2 - APPLICATION OF FULL COLLECTIVE PITCH

VIEW SHOWS AN
ADVANCING BLADE
AT 90° AZIMUTH



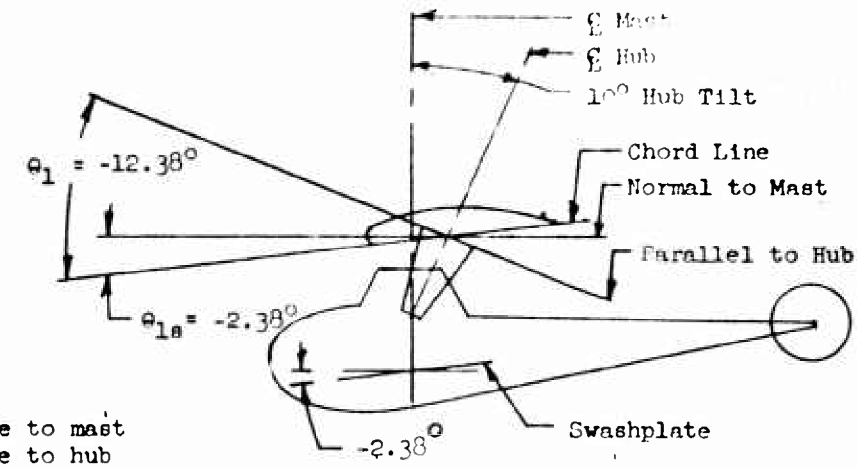
θ_{1s} = Pitch relative to mast
θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAXIMUM STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
12°-7.6°=4.4° at pitch arm	-9.5° + 4.4° =-5.1° (Blade Nose Down)	+9.5°+ 4.4° =+13.9° (Blade Nose Up)

2.5G MANEUVER CONDITION AT 100 KNOTS

STEP 3 - RECOVERY PORTION

VIEW SHOWS AN ADVANCING BLADE AT 90° AZIMUTH

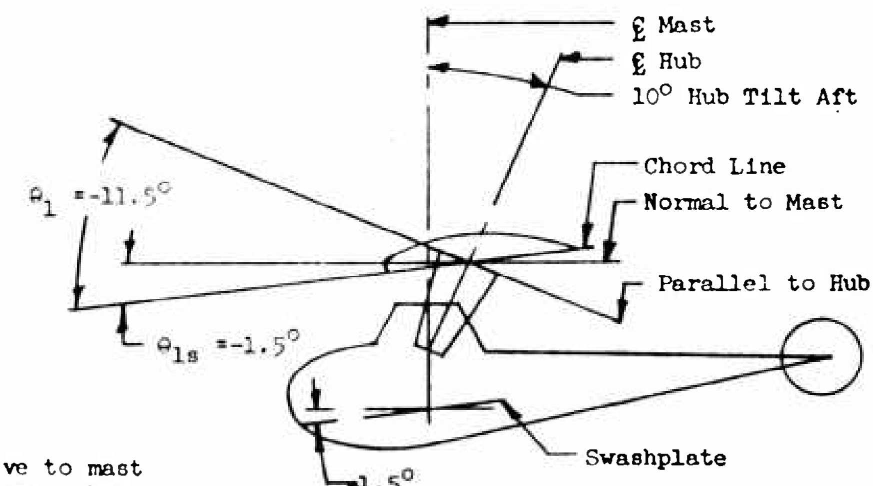


θ_{1s} = Pitch relative to mast
θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAXIMUM STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
12° - 7.6° = 4.4° at pitch arm	-12.38° + 4.4° = -7.98° (Blade Nose Down)	+12.38° + 4.4° = +16.78° (Blade Nose Up)

2.5G AUTOROTATION MANEUVER AT 100 KNOTS "FLAREOUT"

VIEW SHOWS AN ADVANCING BLADE AT 90° AZIMUTH



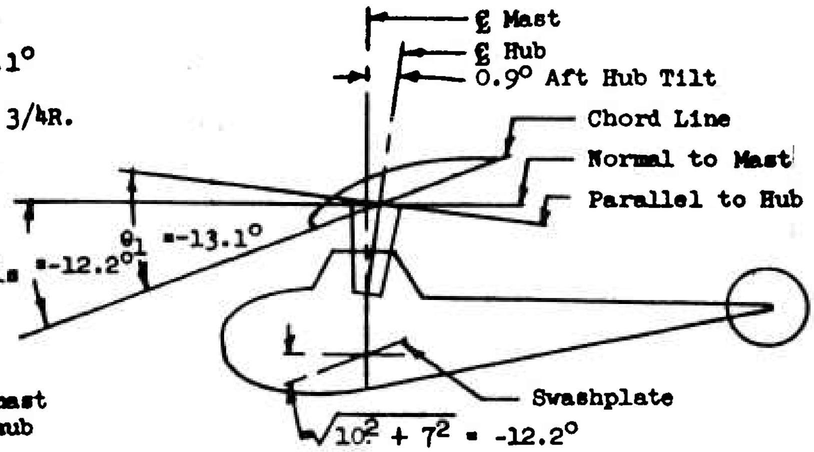
θ_{1s} = Pitch relative to mast
θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAXIMUM STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
3° - 7.6° = - 4.6° at pitch arm	-11.5° + 4.6° = -16.1° (Blade Nose Down)	+11.5° - 4.6° = +6.9° (Blade Nose Up)

STRAP WINDUP

IDLING CONDITION - HUB TILT AFT

Hub Tilt Aft; to follow swashplate but may lag* by 13.1°
cyclic pitch - 12.2°
collective pitch 0° to 12° at 3/4R.



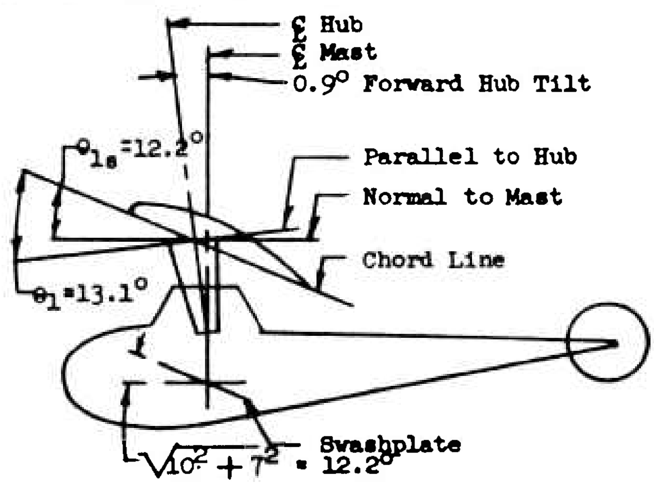
VIEW SHOWS AN ADVANCING BLADE AT APPROXIMATELY 135° AZIMUTH

θ_{1s} = Pitch relative to mast
θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAXIMUM STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
0° - 7.6° = -7.6° at pitch arm	-13.1°-7.6° = -20.7° (Blade Nose Down)	+13.1°-7.6° = +5.5° (Blade Nose Up)
12°-7.6° = +4.4° at pitch arm	-13.1°+4.4° = -8.7° (Blade Nose Down)	+13.1°+4.4° = +17.5° (Blade Nose Up)

IDLING CONDITION - HUB TILT FORWARD

Hub Tilt Forward; to follow swashplate but may lag* by 13.1°.
cyclic pitch +12.2°
collective pitch 0° to 12° at 3/4R.



VIEW SHOWS AN ADVANCING BLADE AT APPROXIMATELY 135° AZIMUTH

θ_{1s} = Pitch relative to mast
θ_1 = Pitch relative to hub

COLLECTIVE PITCH	MAXIMUM STRAP WINDUP	
	ADVANCING BLADE	RETREATING BLADE
0° - 7.6° = -7.6° at pitch arm	+13.1° -7.6° = +5.5° (Blade Nose Up)	-13.1° -7.6° = -20.7° (Blade Nose Down)
12° - 7.6° = +4.4° at pitch arm	+13.1° + 4.4° = +17.5° (Blade Nose Up)	-13.1° + 4.4° = -8.7° (Blade Nose Down)

*Hub Lag $= 2.88° \times \frac{\text{Normal RPM}}{\text{Idle RPM}} = 2.88° \times \frac{243}{53.5} = 13.1°$

Date: 25 November 1959

1.6 CALCULATED OPERATING TEMPERATURES OF STRUCTURAL AND MECHANICAL COMPONENTS

This section contains the operating temperatures used in the design of the Hot Cycle Rotor. Temperatures given on the following pages are based on the thermal analysis of Report 285-10. The Temperature Location Chart on the following page locates by number all critical components. Following the chart the components are listed and temperatures given along with a statement of the local conditions. All component temperatures are based on a gas temperature of 1200°F. at an ambient air temperature of 100°F.

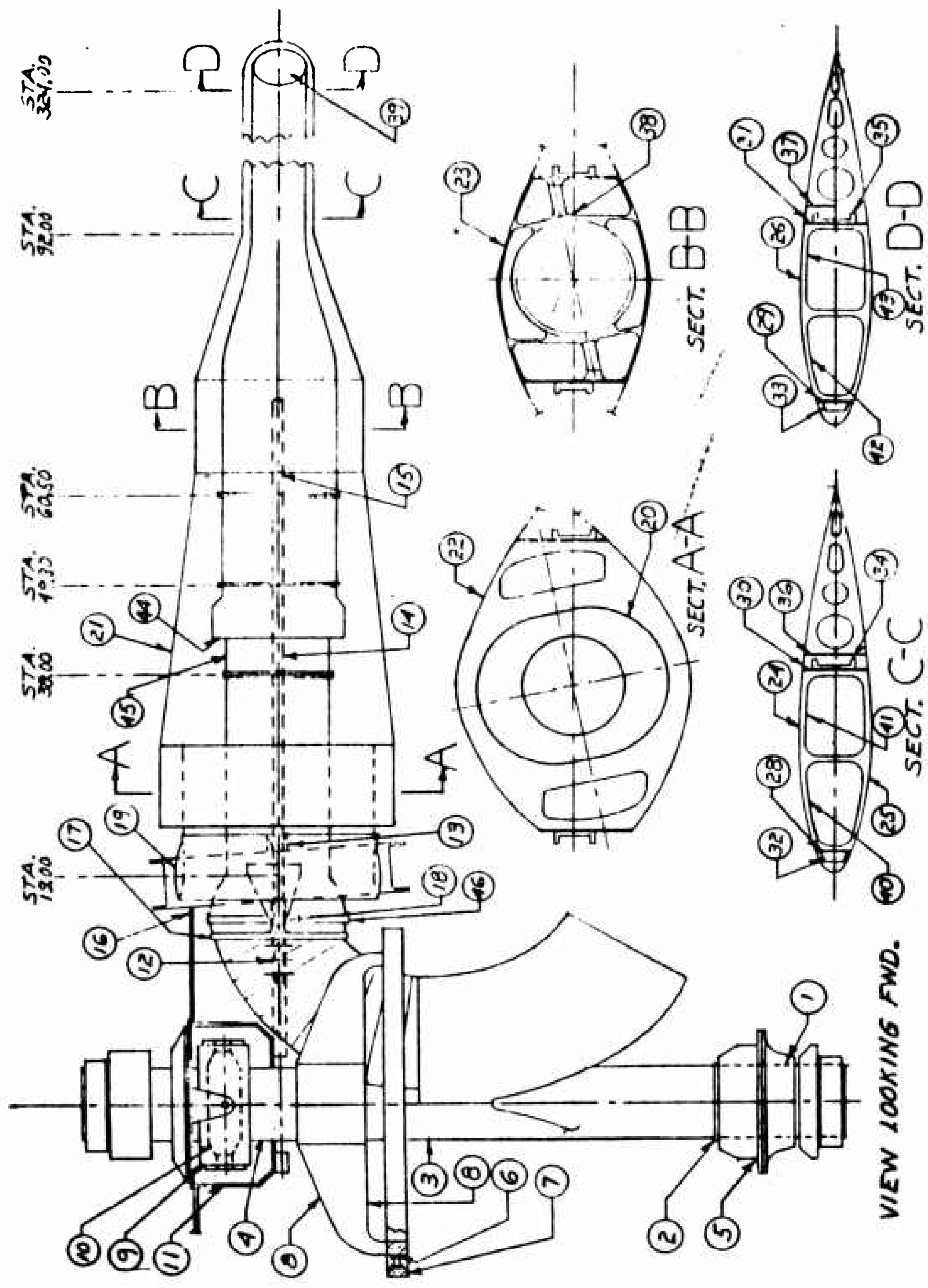


Figure 1-1. Temperature Location Chart

General Conditions:

Reference: Hot Cycle Thermal Analysis, Report 285-10
Duct Temperature 1200°F
Ambient Air Temperature 100°F
Altitude Sea Level
Duct surfaces and/or shielding, unless otherwise noted:

a. Blade constant section — Ducts bare; shield of cres, aluminum coated

b. Blade root and hub — Duct thermal resistance equal to an emissivity of 0.04

A general relationship for correcting the temperatures given in this summary to equivalent values at other operating gas temperatures is:

$$T_x = 100 + \frac{(T_{gas} - 100)}{1100} (T_{ox} - 100)$$

where:

T_x = location temperature at new gas temperature

T_{gas} = new gas temperature

T_{ox} = location temperature at 1200°F gas temperature

This relationship assumes all material properties remain constant with changes in temperature, which is sufficiently accurate over a limited range of temperatures (approx $\pm$ 300°F).

Location No.	Name of Component	Local Conditions	Temp. (°F)
1	Mast at thrust bearing lower region	Steel Mast, Cad Plated. An Aliron shield with 1/4 in. air gap is required over the upper surface of the bearing. No shield should be used on the lower surface which would interfere with the natural convection cooling.	150°

Location No.	Name of Component	Local Conditions	Temp. (^{o}F)
2	Mast just above thrust bearing	Steel Mast, Cad Plated	370^{o} without shield. 160^{o} if 1/4 air gap Aliron shield applied to mast.
3	Mast 16.00 below tilt axis	Steel Mast, Cad Plated. Aliron shields with 1/4 air gap are required on the duct above and below the seal. A shield should be also included between the seal and the mast to deflect leakage air away from the mast.	Av. 360^{o} Max. 500^{o}, under the titanium spacers
4	Mast just below rotor gimbal	Steel Mast, Cad Plated. No shielding is required on the mast. The 1/4 in. gap Aliron shield is required on the duct.	250^{o}
5	Thrust bearing housing	Alum. Alloy Housing, Anodized. Shield as specified in Location 1.	240^{o}
6	Inner (stationary) support ring for radial bearing	Steel Ring, Cad Plated Air gap noted for Location 7.	150^{o}
7	Outer (rotating) support ring for radial bearing	Steel Ring, Cad Plated 0.2 inch gap between ring and air seal.	140^{o}
8	Bottom and Top of Spokes	Steel Spokes, Cad Plated. A thermal conductivity of 0.4 Btu/hr - ft - F was assumed for the insulation block. About 20 percent of the heat is conducted through the .08 inch titanium foil around the block.	590^{o} above the support blocks 400^{o} at the shaft

Location No.	Name of Component	Local Conditions	Temp. (^{o}F)
9	Rotor Gimbal Ring	Alum. Alloy Gimbal, Anodized	170^{o}
10	Rotor Gimbal Trunion	Alum. Alloy Gimbal, Anodized	175^{o}
11	Tilting Hub Inner Ring	Steel Ring, Cad Plated	200^{o}
12	Hub Strap Attach Plates at Center Strap Bolt	Steel Plates, Cad Pladed. Aliron Sheild over duct only	250^{o}
13	Blade Strap at Inboard Fitting	Cor. Res. Stl, Bare	250^{o}
14	Blade Strap at Sta. 40	Cor. Res. Stl, Bare	160^{o}
15	Blade Strap at Outboard Shoe Tangent Point	Cor. Res. Stl, Bare	260^{o}
16	Floating Hub Inboard of Flapping-Feathering Bearing	Steel, Cad Plated	120^{o}
17	Articulate Duct Gimbal Ring	Steel, Nickel Plated Cooling air circulated inside a radiation shield	200^{o} without leakage 270^{o} with 1% leakage
18	Articulated Duct Gimbal Bearing	Cor. Res. Steel Bracket, bare	350^{o}
19	Flapping-Feathering Bearing Ball	Alum. Alloy Ball	400^{o}
20	Blade Inner Surface Sta. 28	Alum. Alloy, Alclad	215^{o}

Location No.	Name of Component	Local Conditions	Temp. (^oF)
21	Blade Skin, Sta. 33 to 63	Alum. Alloy, Alclad	280^o
22	Blade Skin at Sta. 28	Alum. Alloy, Alclad	140^o
23	Blade Skin at Sta. 73	Alum. Alloy, Alclad	215^o
24	Blade Upper Skin at Sta. 92	Cor. Res. Steel, Bare	Figure 1-3 Page 1.6.10
25	Blade Lower Skin Sta. 92	Cor. Res. Steel, Bare	Figure 1-4 Page 1.6.11
26	Blade Upper Skin * Sta. 210	Cor. Res. Steel, Bare	Figure 1-5 Page 1.6.12
27	Blade Upper Skin * Sta. 330	Cor. Res. Steel, Bare	Figure 1-6 Page 1.6.13
28	Blade Fwd. Segment Fwd. Web at Sta. 92	Cor. Res. Steel, Bare	414^o
29	Blade Fwd. Segment Fwd. Web at Sta. 324	Cor. Res. Steel, Bare	470^o
30	Blade Fwd. Segment Aft Web at Sta. 92	Cor. Res. Steel, Bare	317^o
31	Blade Fwd. Segment Aft Web at Sta. 330	Cor. Res. Steel, Bare	441^o
32	Blade Front Spar at Sta. 92	A layer of teflon between spar and fwd. segment web	394^o Average

* Differential between top and bottom skin temperatures is small at this radius, less than 40 ^{o}.

Location No.	Name of Component	Local Conditions	Temp. (^{o}F)
33	Blade Front Spar at Sta. 330	A layer of teflon between spar and fwd. segment web	460^{o} Average
34	Blade Rear Spar at Sta. 92	A layer of teflon between spar and fwd. segment web	310^{o} Average
35	Blade Rear Spar at Sta. 330	A layer of teflon between spar and fwd. segment web	435^{o} Average
36	Blade Aft Segment Fwd. Web at Sta. 92	Alum. Alloy web, Alclad	131^{o}
37	Blade Aft Segment Fwd. Web at Sta. 330	Alum. Alloy Web, Alclad	158^{o}
38	Blade Inner Web between ribs at Sta. 63 & 73 (temp at Sta. 73)	Alum. Alloy Web, Alclad	335^{o} (290^{o} for gas temp = 1040^{o})
39	Blade Tip Aft Fairing	Within an exhaust cone having an 11^{o} half angle	1110^{o}
40	Blade Fwd. Duct at Sta. 92	Rene' 41	Figs. 1-3 & 1-4 Pages 1.6.10,11
41	Blade Aft Duct at Sta. 92	Rene' 41	Figs. 1-3 & 1-4 Pages 1.6.10,11
42	Blade Fwd. Duct at Sta. 330	Rene' 41	Figure 1-6 Page 1.6.13
43	Blade Aft Duct at Sta. 330	Rene' 41	Figure 1-6 Page 1.6.13
44	Outboard Articulated Duct Seal Fitting, Sta. 42, (Dwg. 285-0182)	Cres, Type 347, bare	800^{o}

Location No.	Name of Component	Local Conditions	Temp. (^{o}F)
45	Duct Wall, Sta. 42	Cres, Type 347, bare	1170^{o}
46	Inboard Articulated Duct Seal Housing, Sta. 15.5	Cres, Type 17-4PH, bare, Aliron shield with cooling air circulated inside	550^{o} without leakage 950^{o} with 1% leakage

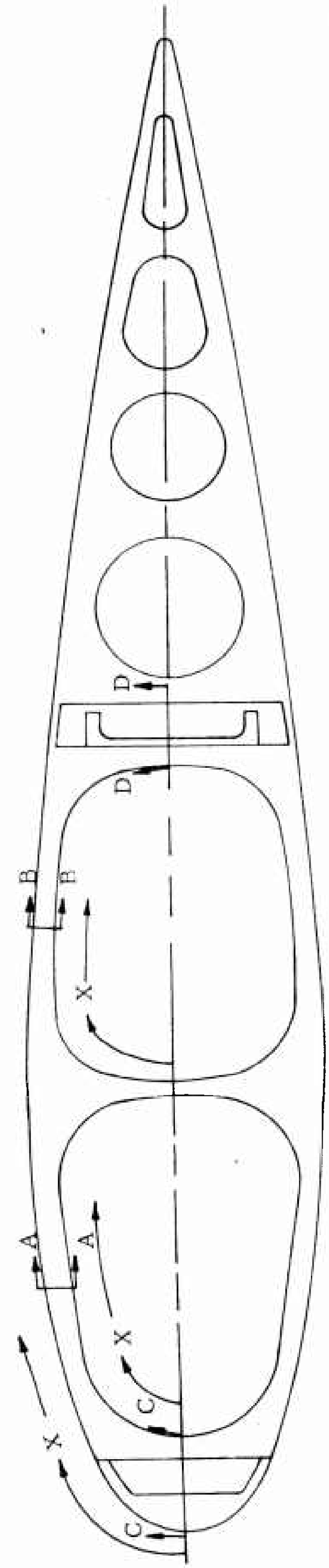


Figure 1-2. Locations for Cross-Sectional Temperature Gradients
Blade Constant Section

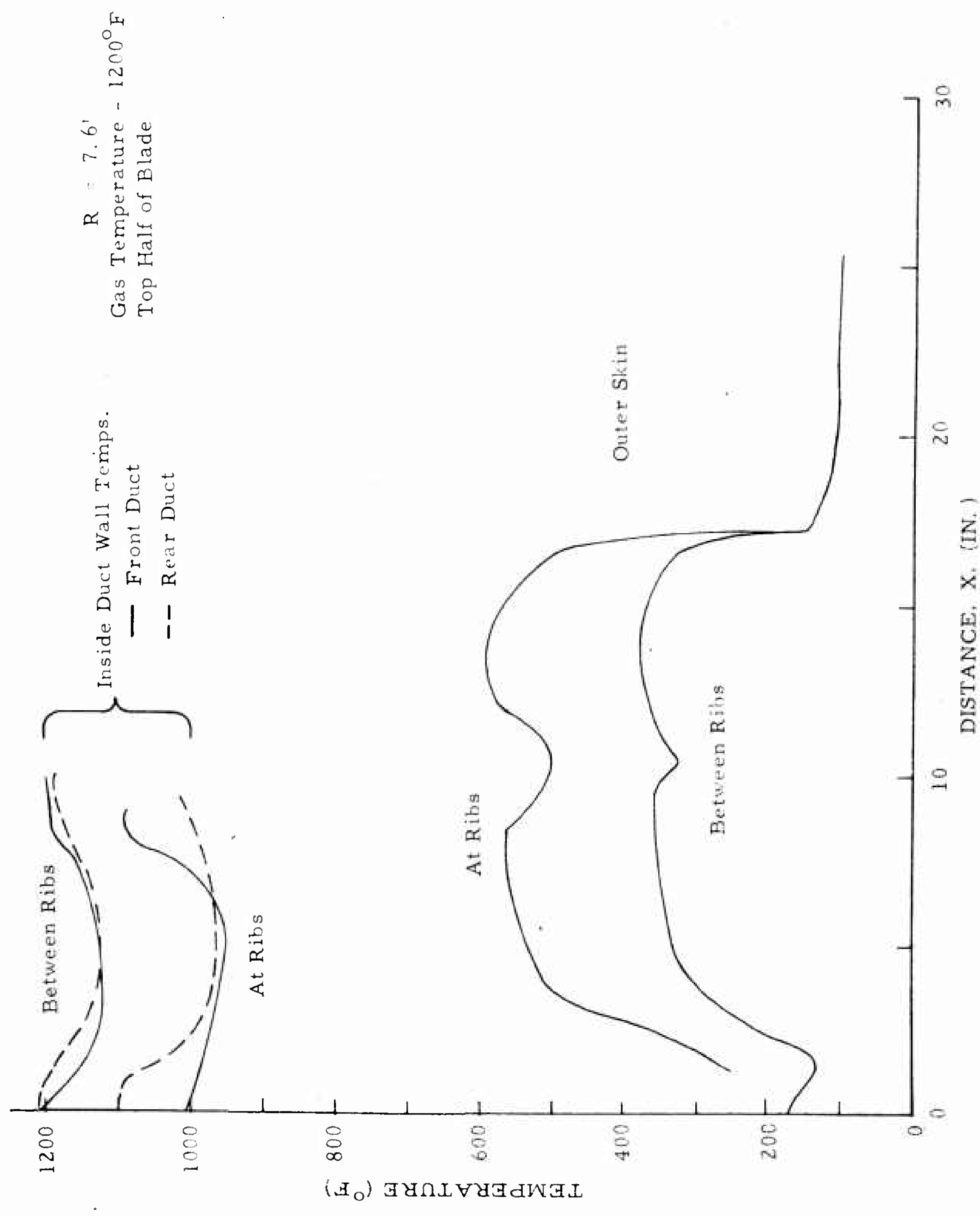


Figure 1-3. Hot Cycle Rotor Blade Temperatures at Steady State

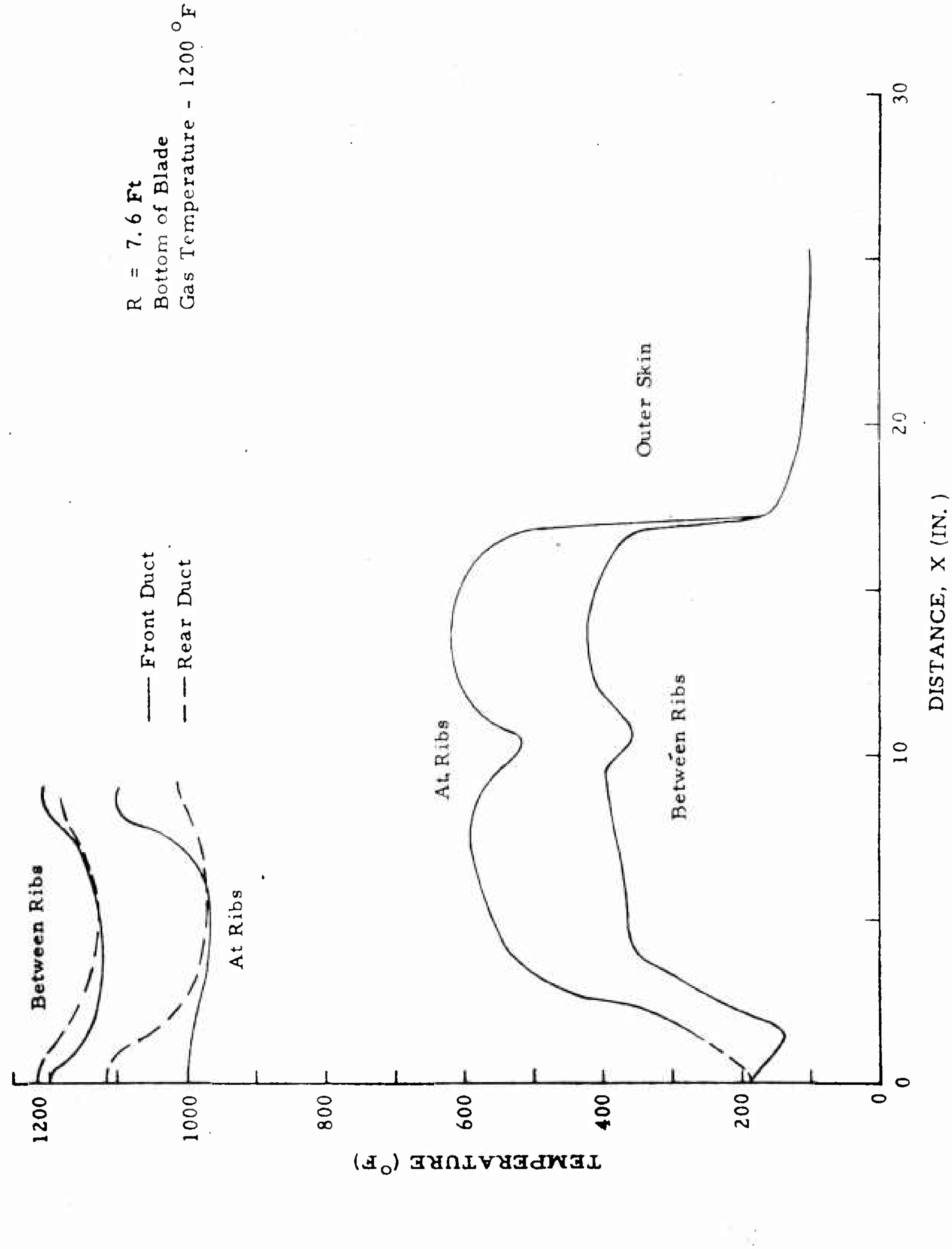


Figure 1-4. Hot Cycle Rotor Blade Temperatures at Steady State

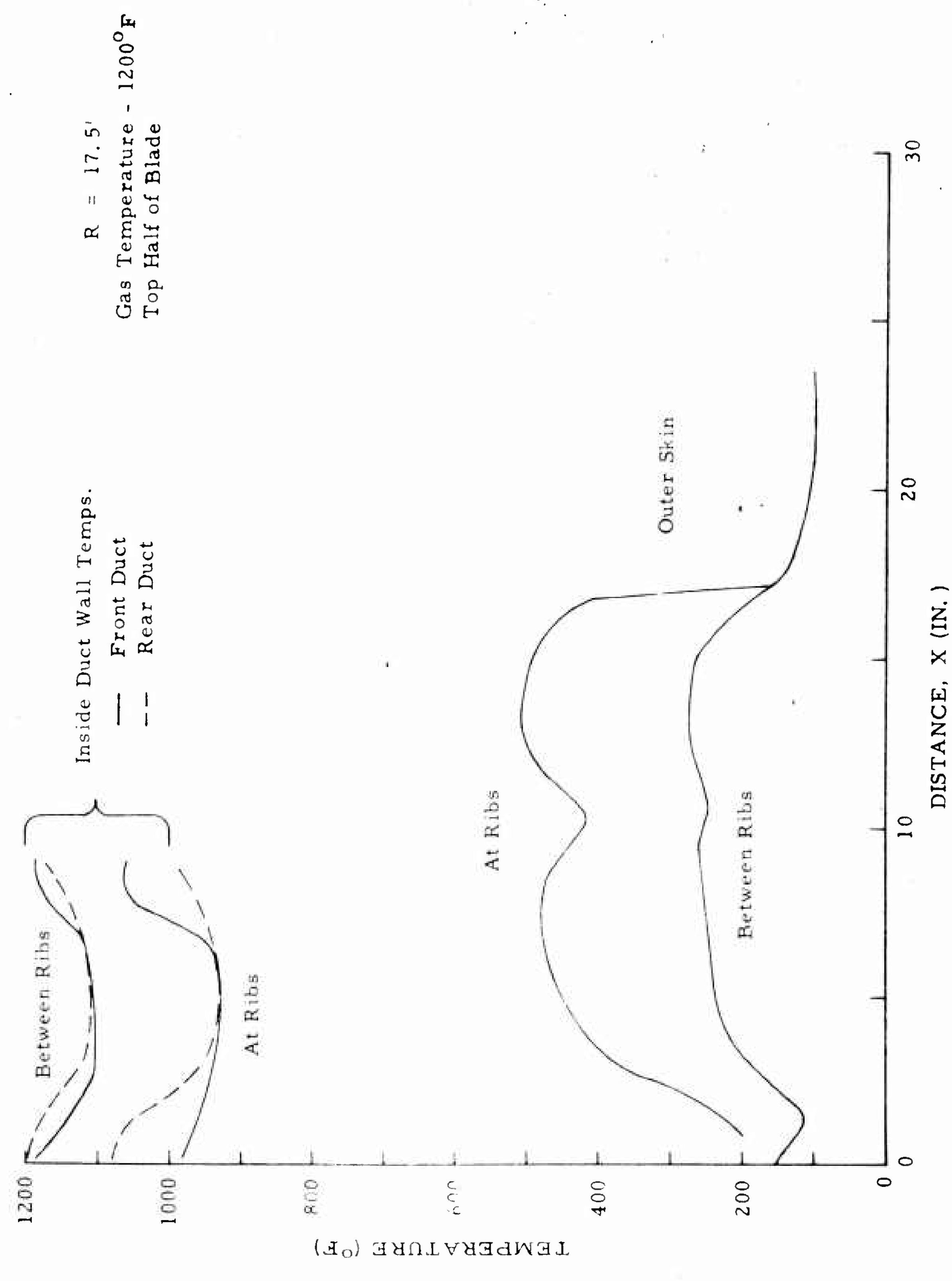


Figure 1-5. Hot Cycle Rotor Blade Temperatures at Steady State

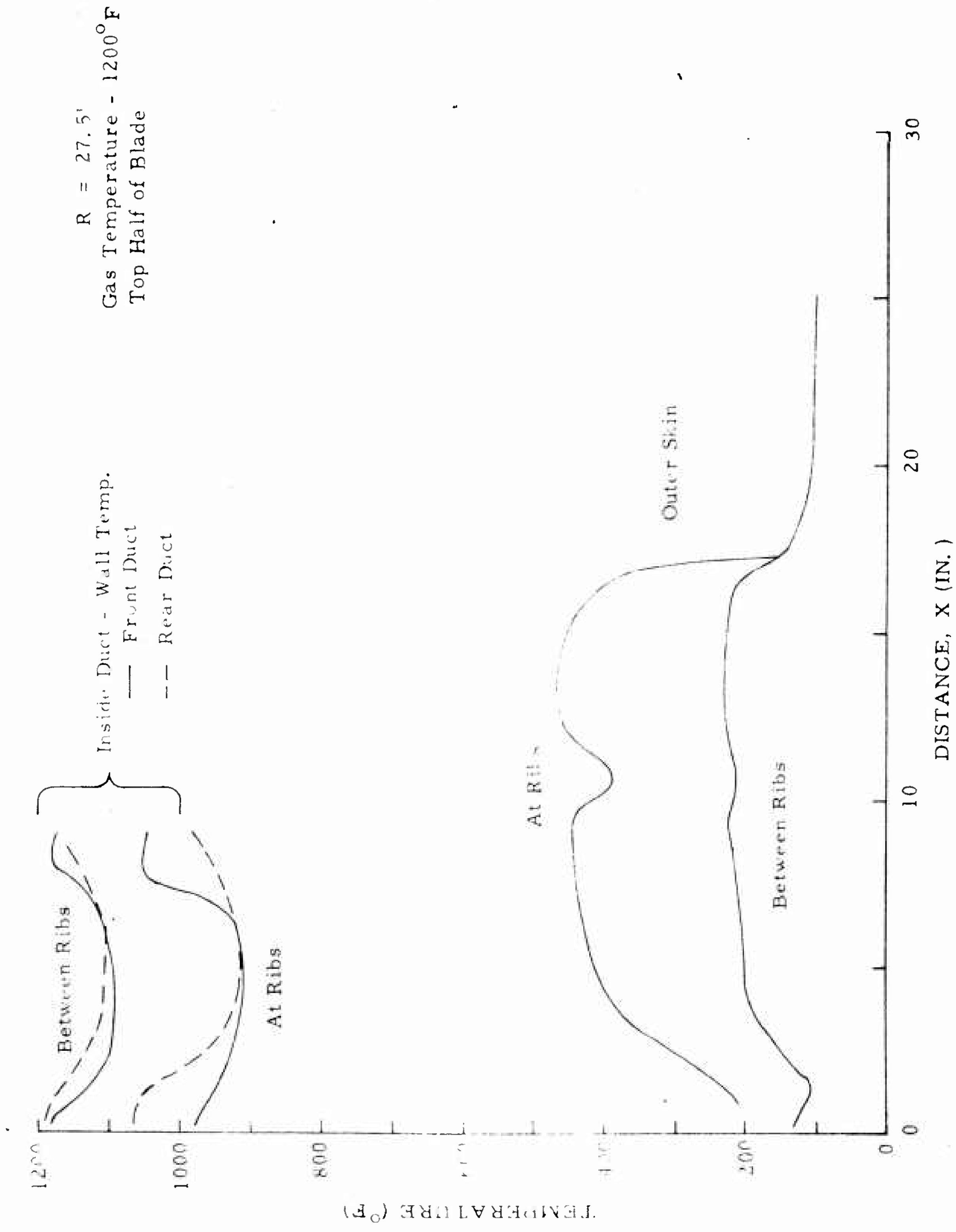


Figure 1-6. Hot Cycle Rotor Blade Temperature at Steady State

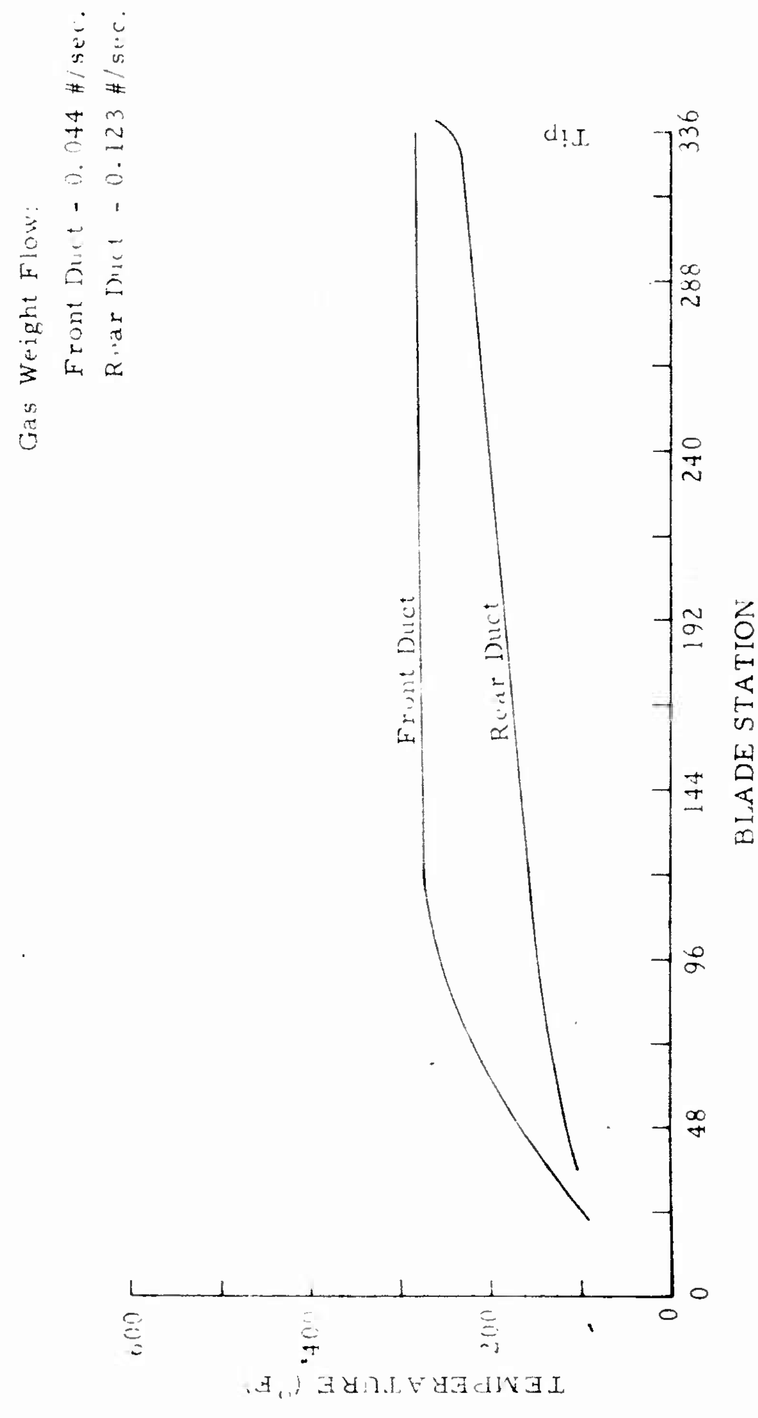


Figure 1-7. Cooling Duct Gas Temperature Vs. Distance Along Hot Cycle Rotor Blade

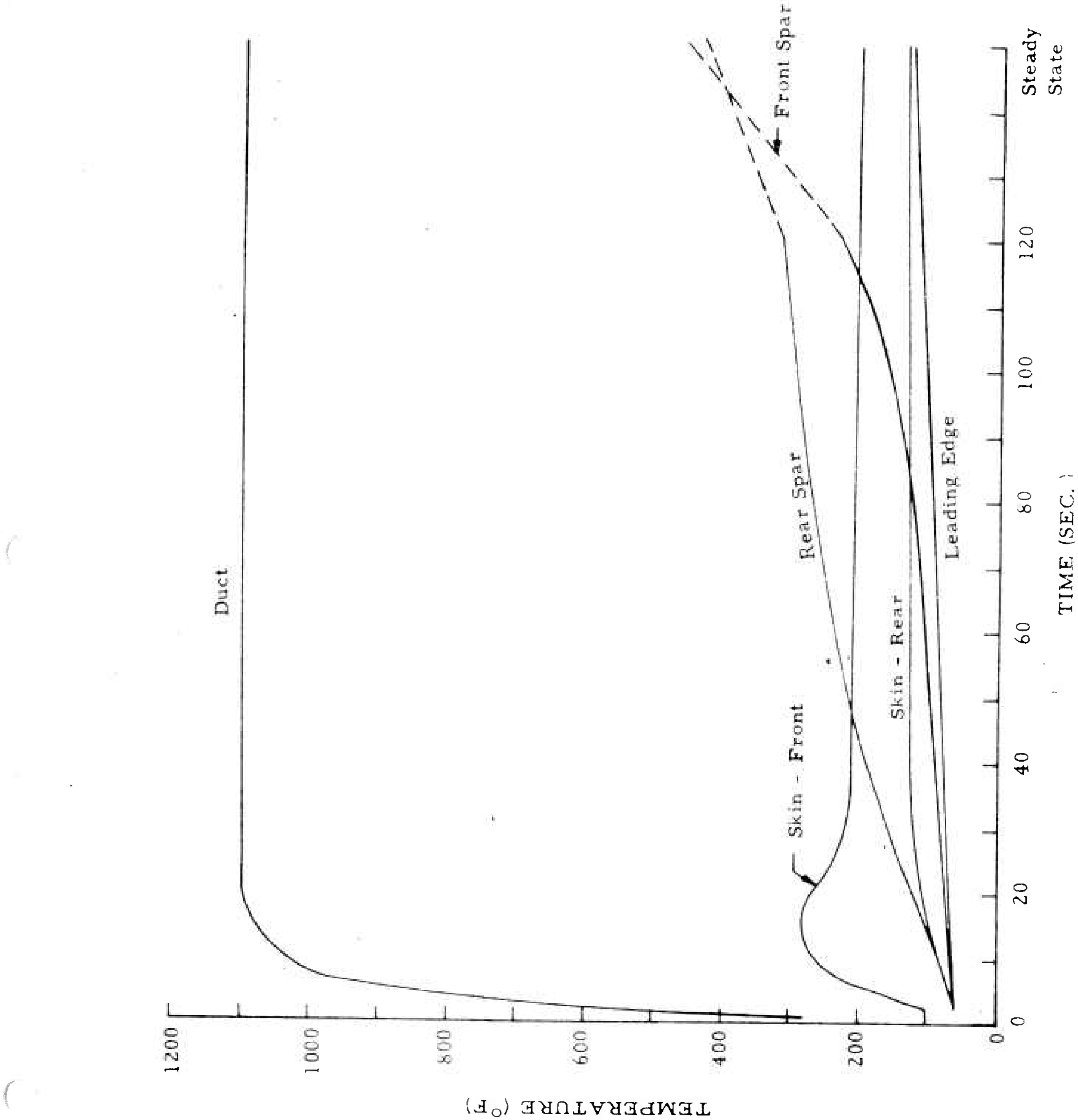


Figure 1-8. Temperature Vs. Time For Hot Cycle Rotor R = 27.5 Ft.

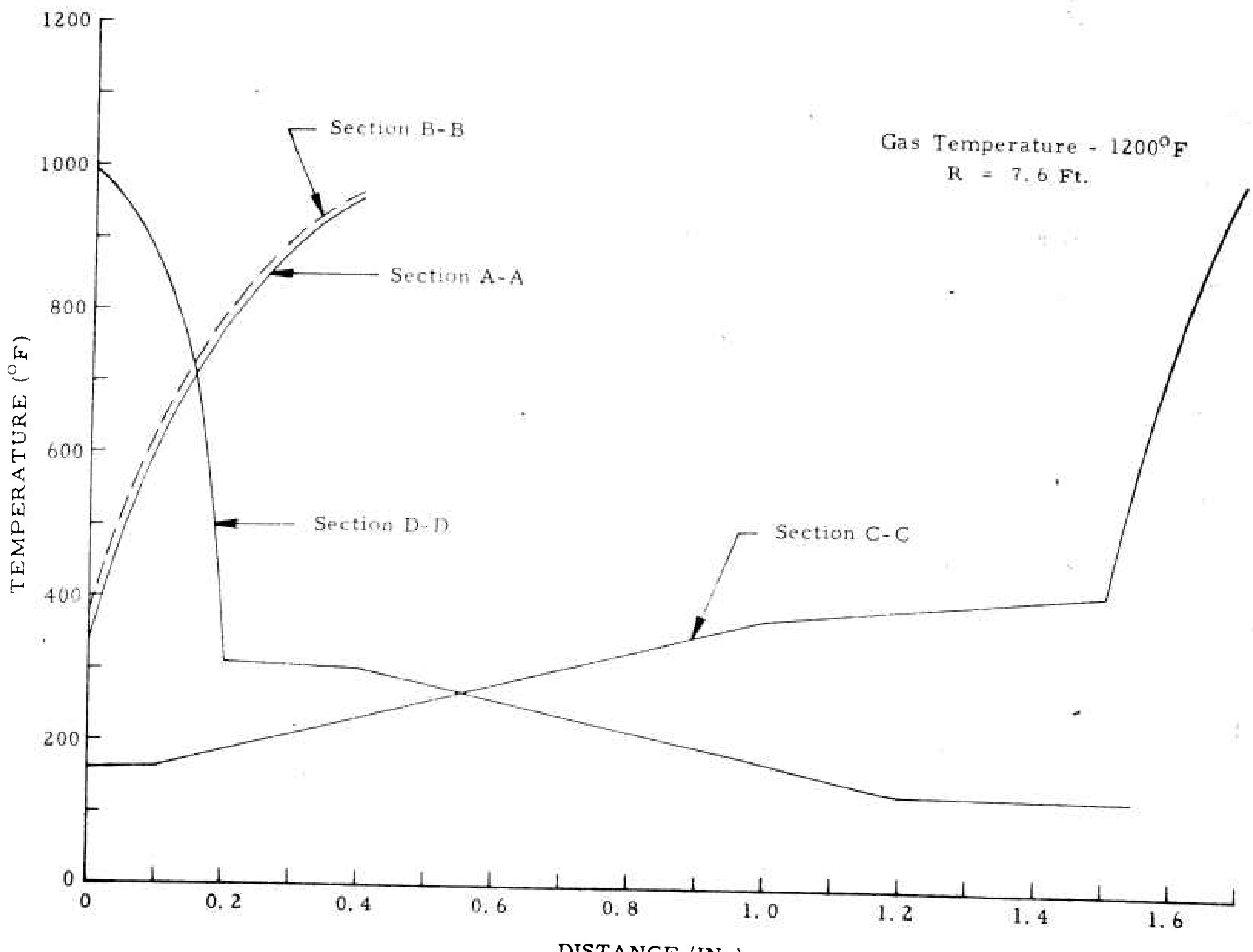


Figure 1-9. Cross-Sectional Temperature Gradients for Hot Cycle Rotor Blade (For Section Locations, See Figure 1-2)

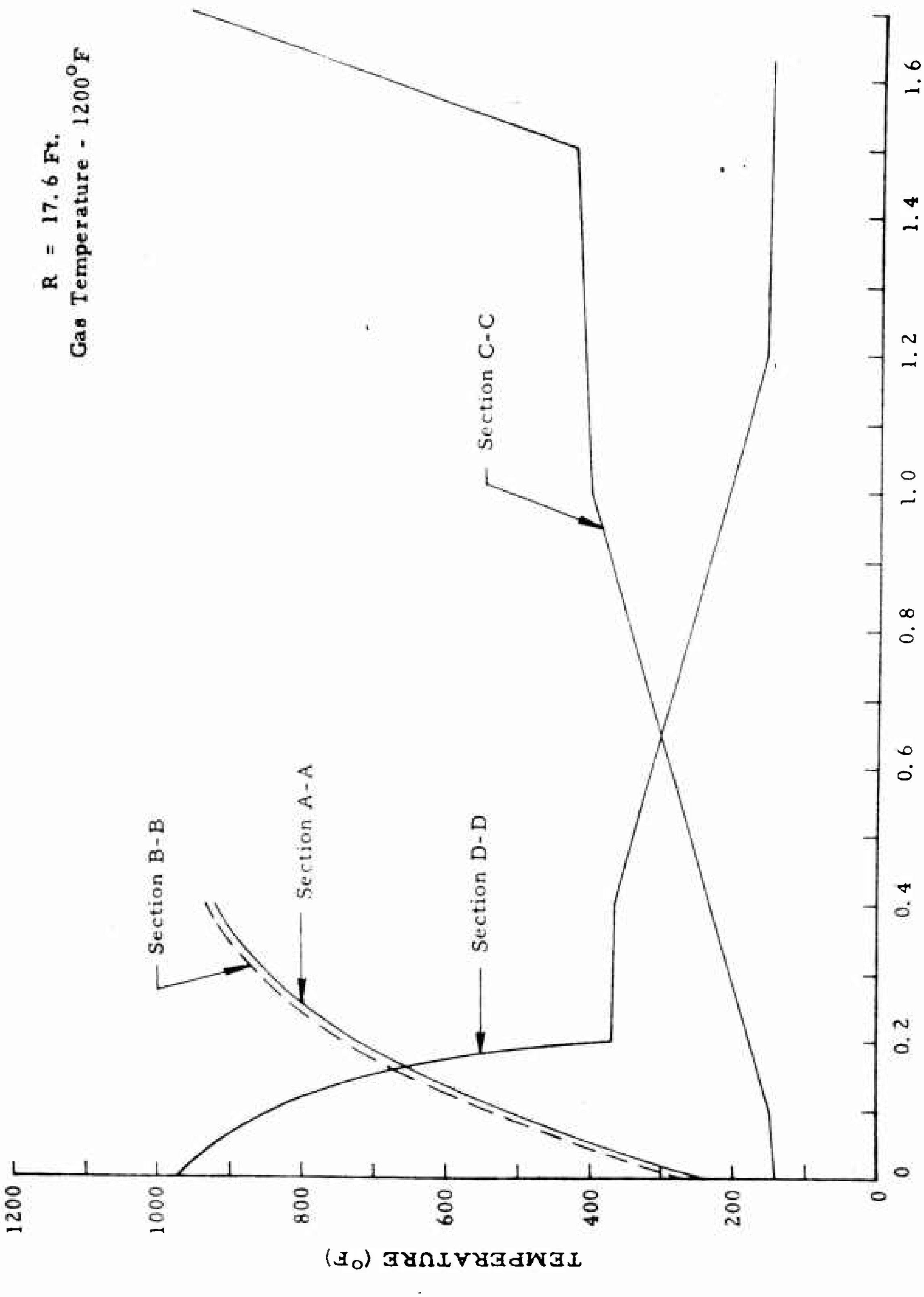


Figure 1-10. Cross-Sectional Temperature Gradients for Hot Cycle Rotor Blade (For Section Locations, See Figure 1-2)

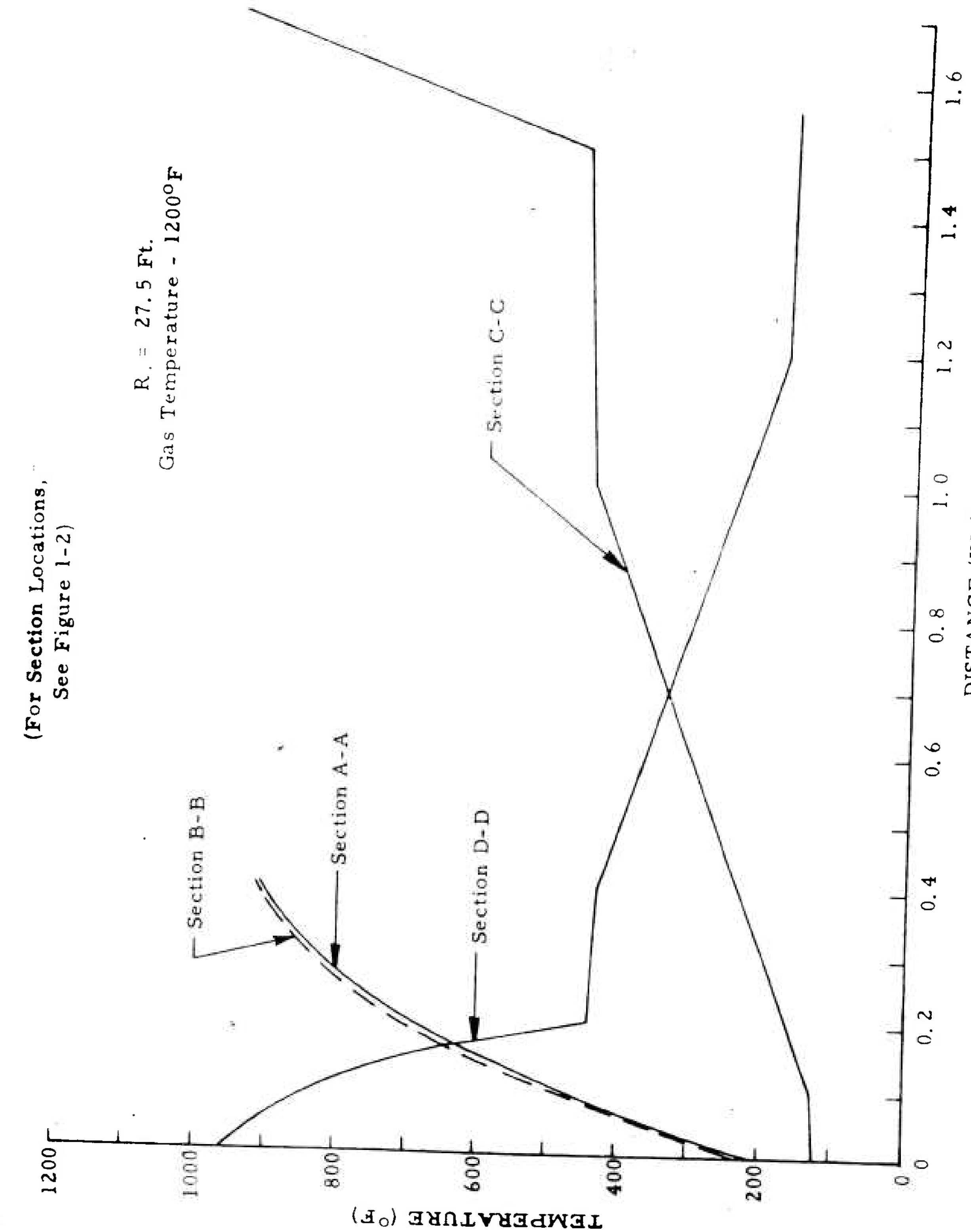


Figure 1-11. Cross-Sectional Temperature Gradients for Hot Cycle Rotor Blade
(For Section Locations, See Figure 1-11)

1.7 MATERIALS AND SURFACE TREATMENT

1.7.1 MATERIALS

1.7.1.1 Rivets

a. Monel rather than stainless steel rivets are to be used where required.

b. AD type rivets shall be used in general in aluminum alloy.

c. DD type rivets may be used in aluminum alloy where their higher strength is essential. (Do not specify Type D.)

d. B type rivets may be used in joining magnesium to magnesium or to any other material.

1.7.1.2 Castings may be used where their method of fabrication results in the best all-around part, cost included. Wrought materials are preferred when no significant cost or weight penalty accrues from their use.

1.7.1.3 Magnesium may be used only where significant weight savings can be gained.

1.7.1.4 Aluminum Alloys

a. 7075, because of reduced strength at temperature, should be used only below 150°F.

b. 2024 may be used at temperatures up to approximately 300°F. Because of its susceptibility to intergranular corrosion, the aged (T6) condition should be specified at temperatures above 250°F; below 250°F, the T3 or T4 condition may be used.

c. 2014 should be used for die and hand forgings at temperatures up to approximately 300°F. To obtain maximum properties, use in the aged (T6) condition.

1.7.2 SURFACE TREATMENT AND COLOR

The finish Spec. HFS-13 is to be called out on all drawings. Nevertheless, temperature considerations on Hot Cycle Helicopter parts require careful selection of color and type of finish. Therefore, HFS-13 does not indicate finishes required

(only the preparation necessary) and the Design Engineer has the responsibility of insuring that the proper selection is made and noted on the drawings. The following data therefore will serve as a guide.

On the external surfaces of structure surrounding a duct, a high emissivity is desirable. On the internal surfaces of structure surrounding a duct, a highly heat-reflective surface is preferable. While this applies especially to the blade and tilting hub, it should serve as a guide for those items where temperature effects are significant.

Relative emissive qualities of various finishes may be obtained from the Technical Engineering Department. Unless significant advantages accrue from a special treatment, however, the standard finishes should be used.

1.7.2.1 Blade Surfaces

Aluminum alloy must be purchased as alclad and should be anodized throughout for maximum corrosion protection, as a base for metal bonding and as a base for paint in case this is desired at a later date. (In addition, drainage must be provided in order to avoid internal corrosion.)

1.7.2.2 Duct

The duct must be isolated from bearings and surrounding structure by an air gap and either a low emissivity coating on the duct itself, or a jacket possessing low emissivity.

1.5.2.3 Types of Finishes Available

a. Stainless Steel parts may be used as is, chemically blackened, liquid honed or polished.

b. Steel parts may be used cadmium plated (For temperatures below 500°F. Cadmium plate must not be used above 500°F.) nickel or chrome plated, metal sprayed, coated by vacuum deposit or painted.

c. Aluminum Alloy Sheet will be specified as alclad and may be left as is or treated as in part d. below.

d. Aluminum Alloy Machined Parts

(1) Oxide surface; anodize for temperatures below 200°F and above.

(2) Chromate surface; chemically treat for temperatures below 200°F.

(3) Black surface; anodize and dye black matte.

e. Magnesium parts will be considered as they occur.

APPENDIX 2

FINISH SPECIFICATION

APPENDIX 2

FINISH SPECIFICATION

As noted in Section 1-7, the temperature of various components differed in accordance with their proximity to the ducting. Selection of type of finish, therefore, was the responsibility of the designer, and was noted in all cases on the drawings. This specification, therefore, lists only the method of finishing.

HUGHES TOOL COMPANY
AIRCRAFT DIVISION

TITLE

FINISH SPECIFICATION
FOR
HOT CYCLE HELICOPTER

8 March 1960 **REPORT NO.** HFS-13

NO. PAGES ________ NO. PHOTOGRAPHS ________

PREP. BY ________ APPROVED BY ________

DATE	REVISED BY	PAGES	REMARKS
11-5-60	R. E. Katherman	SectionV	Addition of Paragraph III
12-28-60	W. Jones	Page 6	Section VIII

FORM 9702

SECTION I.

CLEANING OF PARTS

1. GENERAL REQUIREMENTS

   A. All metal surfaces shall be cleaned in accordance with the requirements in Specification MIL-S-5002, and the following:

      1. All parts shall be free of oil, grease, paint, scale, rust, flux, etc., prior to painting, plating or chemical treatment such as anodizing, parkerizing, etc.

      2. Ferrous parts shall not be acid pickled. Liquid honing or equivalent shall be used for scale removal.

      3. Parts shall be rapidly dried and inspected with a minimum of handling to avoid soiling of the surface prior to applying protective finishes.

      4. Parts subject to delay between surface preparation and the first organic coat shall be cleaned with solvent conforming to Specification P-S-661 prior to applying the first coat.

      5. Vapor degreasing shall be accomplished with trichlorethylene, MIL-T-7003, suitably inhibited for use as a metal cleaner. Carbon tetrachloride shall not be used for degreasing.

SECTION II

TREATMENT OF CORROSION, HEAT RESISTANT ALLOYS AND TITANIUM ALLOYS

I. GENERAL

a. Corrosion resistant steel (300 and 400 series and 17-7PH and 17-4PH shall be passivated after pickling, vapor honing, forming, welding (except spot welding), machining, filing, or other fabricating process which either removes metal from the surface, or leaves particles of foreign metal on the surface (as from forming dies).

b. Formed or machined parts to be spot welded shall be passivated prior to the spot welding operations.

c. Scale shall be removed by suitable mechanical process.

d. Any abrasive used in plating is to be non-metallic and shall not have been used on other metal or alloys.

e. Passivating shall be performed per HP 4-8.

II. PAINTING

a. Where it is necessary to paint corrosion resistant steel, the surface shall be treated as follows:

1. Remove oil, grease, etc., by wiping with a cloth dampened in wash thinner or equivalent.
2. Wipe surface with a cloth dampened with WO-1, manufactured by Turco Products Corporation. Allow to remain 3-5 minutes.
3. Remove WO-1 by wiping with a cloth dampened with clear water. Dry surface.
4. Finish as required on surrounding surface.

SECTION III.

TREATMENT OF ALUMINUM ALLOYS

I. ANODIC AND CHEMICAL FILMS.

A. As much forming, drilling, cutting, etc., as practicable shall be performed on parts prior to surface treatment. If surface treatments are damaged or removed by machining the parts shall be touched-up per HP 4-57.

II. SERVICE LINES (FLUIDS AND GASES, EXCEPT OXYGEN) AND ELECTRICAL CONDUIT

A. Service lines (except oxygen) and electrical conduit aluminum alloys 1100, 3003, 5052 and 6061, shall be chemically treated and given one coat of primer. The fittings or beaded ends over which hose sections are to be installed shall be masked free of primer.

B. 2024-T4 Aluminum Alloy lines shall be anodized before fittings have been installed and shall be given one coat of primer after installation of the fittings which shall be masked free of primer.

C. Lines which are exposed to temperatures above 200°F shall not be primed.

SECTION IV

TREATMENT OF COPPER AND COPPER BASE ALLOYS

I. COPPER LINES

A. No finish required.

II. TINNED PARTS

A. Electrical terminals and copper bonding braid shall be purchased tinned.

SECTION V.

CORROSION PREVENTION - GENERAL INFORMATION

I. GENERAL PRECAUTIONS

A. Unless otherwise specified, the overlapping portions of all metal joints, except hot joints (250°F or higher) and seams, shall receive at least one coat of zinc chromate primer on each contacting surface.

B. Special care shall be taken that metal particles, screws, nuts, etc., are not lodged in inaccessible sections as they may be a serious source of corrosion.

C. Steel wool shall not be used on aluminum. Corrosion resisting steel wool may be used on aluminum providing all particles resulting from its use are carefully removed from the surfaces.

D. Leather shall not be used in contact with any metal structural parts. Leather may be used in contact with non-structural parts, but will cause excessive corrosion when in contact with aluminum alloys and should be used only when necessary.

E. Welded parts shall be cleaned of all flux as soon as practicable after welding.

F. Joints and faying surfaces shall not contain materials subject to deterioration in chemical treating baths.

G. The interior surfaces of gear boxes or other parts subject to continuous exposure to oil, fuel, grease or hydraulic fluid shall not be painted.

H. Areas in which paint or paint failures would cause malfunctioning of the part shall not be painted. Adhesive bonded areas shall not be painted.

II. FASTENERS

A. Rivets do not require touch-up after driving.

B. No organic finish shall be required on bolts, screws, rivets and nuts before installation (except as noted in D).

C. Close tolerance bolts shall be coated with zinc chromate compound (Fuller RL 3700) before installation, or installed in holes that have received a coat of zinc chromate compound just prior to installation. (Maximum temperature, 250°F).

III. WASHERS

A. If manufacturing tolerances of bolted joints make necessary additional washers, use the same as specified on the drawings. If none are specified, AN960D washers shall be used against aluminum alloy and plated steel and AN906C washers shall be used against corrosion resistant steel parts. Whenever practicable, the thinnest standard washers shall be employed.

IV. RUBBER SURFACES

A. Do not paint or grease rubber parts without specific approval of the Chief Process Engineer.

V. PRESS FITS

A. Press fits, such as bushings and bearings shall be installed per HP 15-38. Steel or copper alloys, except oil impregnated bearings, shall have the surfaces, which contact aluminum alloys, flash cadium plated (.0001) prior to assembly.

VI. DISSIMILAR METAL

A. Dissimilar metal, as defined in MS33586, shall be insulated by the application of at least one coat of zinc chromate primer to each of the contact surfaces.

VII. TREATMENT OF JUNCTION BOXES

A. Aluminum and aluminum alloy junction boxes shall be chemically treated per HP 4-57 or anodized per HP 4-2, and the interior surfaces coated with General Electric Company's Glyptal Varnish No. 1202.

VIII. TOUCH UP OF FINISHED PARTS

Ferrous parts which have a small portion of the protective finish removed by machining, etc., shall have the unprotected area refinished with PT-805 Aluminum Coating.

1. If possible, cure coated area at 200°F for 1 hour with infrared light. If not possible, allow to cure for 24 hours at room temperature before handling.

2. Manufactured by Products Techniques, Inc. Los Angeles, California

SECTION VI.

I. ELECTRICAL BONDING

A. Electrical bonding shall be in accordance with Specification MIL B-5087 (HP 14-13).

B. The bonding areas of aluminum alloy parts shall have all organic or anodic films removed prior to assembly. The bonding areas shall be treated per HP 4-57. Surrounding area shall be painted as required after assembly.

C. Bonding straps attached to aluminum parts shall be assembled with 5052 aluminum alloy washers and to ferrous parts with stainless steel or cadmium plated steel washers.

II. ELECTRICAL WIRES

A. Wires shall be identified in accordance with Specification MIL W-5088 (HP 8-7), Wiring, Installation of Aircraft.

III. ELECTRICAL CONDUIT

A. Electrical conduit need not be painted prior to installation.

IV. PHENOLICS

A. All phenolic parts used in electrical assemblies and all other phenolic parts with exposed machined surfaces shall be water proofed with one coat of Glyptal Varnish No. 1202 or equivalent, except when such coating interferes with the function of the part.

APPENDIX 3

LIST OF ROTOR SYSTEM DRAWINGS

TABLE NO. 1

HOT CYCLE ROTOR SYSTEM DRAWINGS

DRAWING NO.	TITLE
285-0004	Test Installation - Hot Cycle Whirl
285-0005	Rotor Assembly - Hot Cycle
285-0100	Blade Assembly - Hot Cycle Main Rotor
285-0171	Tip Assembly - H.C.R.B. Forward
285-0172	Cascade Assembly - H.C.R.B. Forward
285-0173	Tip Assembly - H.C.R.B. Aft
285-0187	Fairing - Blade Tip Aft
285-0117	Segment Assembly - H.C.R.B. Aft
285-0167	Segment Installation - H.C.R.B. Forward
285-0113	Segment Assembly - H.C.R.B. Forward
285-0114	Rib - H.C.R.B. Forward
285-0191	Shield Installation - Forward Segment
285-0165	Coupling Assembly - H.C.R.B. Segment Flexure
285-0193	Flexure - Forward Segment Coupling
285-0203	Coupling Assembly - Wrought
285-0199	Flexure Assembly
285-0138	Structure Installation - H.C.R.B. Station 74.00 to 91.00
285-0139	Structure Installation - H.C.R.B. Station 63.00 to 73.00
285-0128	Rib - H.C.R.B. Station 63.00
285-0129	Rib - H.C.R.B. Station 73.00
285-0163	Fitting - H.C.R.B. Strap Attach Front Spar
285-0164	Fitting - H.C.R.B. Strap Attach Rear Spar
285-0159	Duct Installation - H.C.R.B. Station 15.50 to 92.00
285-0228	Clamp Fitting - Duct Joining
285-0160	Duct Assembly - Inboard Articulated
285-0180	Housing Assembly - Inboard Articulated Duct Seal
285-0178	Ring Assembly - Duct Gimbal
285-0179	Duct Assembly - Inboard Articulated Sta. 15.50 to 37.5
285-0131	Bracket - Articulated Duct Support
285-0175	Ball Assembly - Articulated Duct
285-0218	Fail Safe Instal. - Articulate Duct Gimbal
285-0194	Turnbuckle Assembly
285-0137	Duct Assembly - Station 49.00 to 60.50
285-0141	Clamp - Duct Joining
285-0136	Ring - H.C.R.B. Duct
285-0196	Clevis - Outboard Duct Hold Back
285-0195	Duct Assembly - Station 88.06 to 91.93
285-0162	Housing Instal. - Articulate Duct Outboard Seal
285-0156	Segments - Articulate Duct Outboard Seal
285-0181	Housing Assy. - Articulate Duct Outboard Seal
285-0168	Fitting - Outboard Articulate Duct
285-0182	Fittings - Outboard Articulate Duct Support
285-0169	Spring - Outboard Articulate Duct Garter
285-0161	Ring - Outboard Articulate Duct

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DRAWING NO.	TITLE
285-0185	Spring - Outboard Articulate Duct Press
285-0186	Spring - Outboard Articulate Duct Retainer
285-0204	Modification Drawing - Articulate Duct Seal
285-0217	Clip Seal Assembly - Nested
285-0132	Duct Assembly - H.C.R.B. Transition
285-0166	Structure Instal. - H.C.R.B. Station 33.00 to 63.00
285-0197	Frames - Flexure Station 34.75, 45.25 and 61.75
285-0127	Structure Instal. - H.C.R.B. Station 25.00 to 33.00
285-0135	Rib - H.C.R.B. Station 33.25
285-0140	Arm Assembly - H.C.R.B. Feathering
285-0126	Ball - H.C.R.B. Feathering Bearing
285-0176	Fitting - H.C.R.B. Station 25.25 to 33.25
285-0190	Rib Assembly - H.C.R.B. Station 24.25
285-0189	Rib Segment - H.C.R.B. Station 24.25
285-0134	Rib - H.C.R.B. Station 24.25
285-0121	Strap Assembly - Hot Cycle Main Rotor Blade
285-0170	Spars - Hot Cycle Main Rotor Blade
285-0155	Bearing Assembly - H.C.R.B. Fabric Feathering
285-0133	Droop Stop Installation - H.C.R.B.
285-0183	Bearing - Droop Stop
285-0223	Doubler Installation - Rear Spar Station 73.00
285-0222	Yoke - Rear Spar Station 73.00
285-0221	Filler - Rear Spar Station 73.00
285-0220	Doubler - Rear Spar Station 73.00
285-0123	Fairing Installation - H.C.R.B. Outboard Nose
285-0124	Fairing Installation - H.C.R.B. Inboard Nose
285-0125	Fairing Installation - H.C.R.B. Inboard Aft
285-0202	Heat Shield - Station 19 to 91 Inboard Duct
285-0198	Shim - Anti-Fretting
285-0300	Controls Installation - HCR Upper Flight
285-0327	Spindle and Support Assembly - Lower Hub Controls
285-0308	Support Assembly - Lower Controls
285-0309	Billet - Lower Support Assembly
285-0311	Mounting Details - Spindle and Slip Ring
285-0335	Drive Link Assembly - Rotor Swashplate
285-0326	Bearings (Reference)
285-0336	Link Assembly - Rotation Swashplate
285-0326	Bearings (Reference)
285-0318	Collar Assembly - Lower Support
285-0312	Swashplate Details - Rotating
285-0325	Billet - Rotating Swashplate
285-0313	Swashplate Details - Stationary
285-0338	Billet - Stationary Swashplate
285-0332	Drag Link Assembly - Stationary Swashplate
285-0326	Bearings (Reference)
285-0316	Centering Bearing Assembly - H.C.R. Swashplate
285-0315	Centering Bearing Cup - H.C.R. Swashplate

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DRAWING NO.	TITLE
285-0314	Centering Bearing Ball - H.C.R. Swashplate
285-0310	Small Parts Details - Control System
285-0307	Control Rod Assembly - Center
285-0326	Bearings - Control System H.C.R.
285-0306	Support Assembly - Control System Upper
285-0305	Control Rod Assembly - Upper Hub
285-0326	Bearings (Reference)
285-0306	Support Assembly - Control System Upper
285-0305	Control Rod Assembly - Upper Hub
285-0326	Bearings (Reference)
285-0303	Torque Tube Assembly - Upper Hub Control
285-0328	Details - Controls Torque Tube Assembly
285-0329	Billet - Torque Tube Assembly
285-0330	Inboard Support - Torque Tube Assembly
285-0331	Outboard Support - Torque Tube Assembly
285-0500	Hub Installation - Hot Cycle Rotor
285-0511	Hub Assembly - Hot Cycle Rotor Tilting
285-0574	Housing Assembly - H.C.H. Feathering Bearing
285-0512	Plate - H.C.H. Droop Stop
285-0513	Shoe - H.C.H. Strap
285-0532	Ring - H.C.H. Tilting
285-0559	Billet - H.C.H. Feathering Bearing Ring
285-0575	Angle - H.C.H. Shoe Bracket Attachment
285-0562	Fitting - H.C.H. Beam Intersection
285-0560	Billet - H.C.H. Beam Intersection Fitting
285-0563	Fitting - H.C.H. Splice
285-0564	Plate - H.C.H. Strap Lower
285-0565	Plate - H.C.H. Strap Upper
285-0566	Web - H.C.H. Side
285-0567	Fitting - H.C.H. Beam Shoe Attach
285-0568	Plate - H.C.H. Tension Tie
285-0569	Cap - H.C.H. Upper Beam
285-0570	Angle - H.C.H. Beam Upper
285-0571	Fitting - H.C.H. Ring Shoe
285-0572	Plate - H.C.H. Tension
285-0573	Web Assembly - H.C.H. Upper
285-0575	Angle - H.C.H. Shoe Bracket Attach
285-0576	Bracket - H.C.H. Shoe to Ring
285-0578	Angle - H.C.H. Web Attach
285-0577	Stop Assembly - H.C.H. 1° Tilt
285-0579	Fitting - H.C.H. 1° Tilt Stop
285-0580	Counterbalance Assembly - H.C.H. 1° Tilt Stop
285-0581	Arm Assembly - H.C.H. 1° Tilt Stop
285-0582	Retainer - H.C.H. 1° Tilt Stop

DRAWING NO.	TITLE
285-0583	Bracket - H.C.H. Closeout
285-0584	Spacer - H.C.H. Droop Stop
285-0514	Gimbal Assembly - Hot Cycle Hub
285-0527	Trunnion Shaft Assembly -HCRH Gimbal
285-0528	Ring Assembly - HCRH Gimbal
285-0529	Fitting - HCRH Gimbal
285-0561	Billet - HCH - Gimbal - Fretting
285-0530	Details - HCRH Gimbal
285-0534	Shaft Assembly - Hot Cycle Hub
285-0517	Shaft - Hot Cycle Hub
285-0515	Spoke - Hot Cycle Hub
285-0555	Blank - Spoke
285-0554	Washer - Radius
285-0552	Inner Ring Assembly - Hub Upper Bearing Housing
285-0553	Outer Ring - Hub Upper Bearing Housing
285-0516	Small Part Details - Hub Upper Bearing
285-0546	Roller Bearing - Rotor Shaft Upper Radial
285-0556	Seal - Hub Upper Support Bearing
285-0518	Spacer - H.C.R. Shaft
285-0524	H.C.R. Hub Thrust Bearing
285-0525	Shim - H.C. Hub
285-0541	Duct Installation - H.C. Hub, Upper
285-0519	Duct Assembly - Upper Rotating
285-0505	Ring - Hub Outer Seal Bearing
285-0540	Ring Assembly - Upper Duct Clamp
285-0588	Spacer and Link - H.C. Hub Upper Duct
285-0589	Block Assembly - Hub Upper Duct Insulator
285-0522	Duct Assembly - Lower Stationary
285-0509	Seals Installation - HCH
285-0141	Clamp (Reference)
285-0507	Gasket - Duct
C-102481-1	Housing
C-102481-2	Carbon Ring
C-102481-3	Carbon Assembly
C-102481-4	Garter Spring
C-102481-5	Coil Spring
C-102978	Face Seal Assembly
B-102979	Mating Ring
285-0533	Spacer - HC Thrust Bearing
285-0543	Sleeve - Hot Cycle Rotor Shaft
285-0585	Installation - H.C.H. Seal
285-0590	Insulation - Hub Ducts
285-0523	Mount Assembly - Hot Cycle Hub
285-0544	Fittings - Upper and Lower Truss

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